Technical Report CHL-99-6
May 1999

US Army Corps of Engineers
Waterways Experiment Station

Coastal Processes Assessment for Brevard County, Florida, with Special Reference to Test Plaintiffs

by *Nicholas C. Kraus, WES*
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Prepared for U.S. Department of Justice

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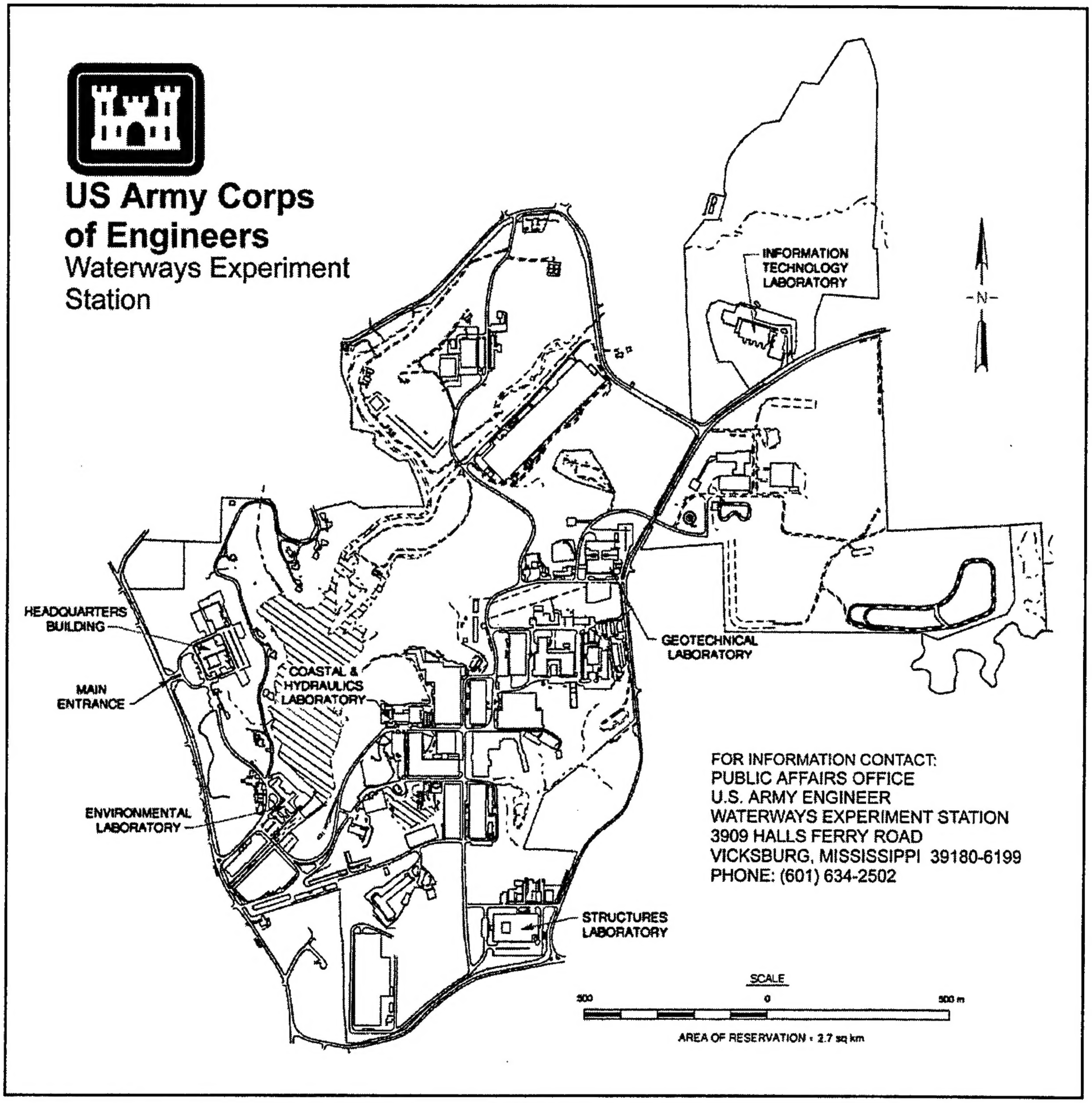

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Preface

The study described herein was performed as an independent assessment of the coastal physical processes occurring along Brevard County, Florida. The study was conducted for the United States Department of Justice, Environment and Natural Resources Division, in its involvement with the lawsuit Applegate et al. v the United States of America. The subject matter focuses on the two test plaintiffs in the lawsuit.

The study was conducted by Dr. Nicholas C. Kraus of the U.S. Army Engineer Waterways Experiment Station (WES), Coastal and Hydraulics Laboratory, Dr. Mark R. Byrnes of Applied Coastal Research and Engineering, Inc., Mashpee, Massachusetts, and Ms. Anne-Lise Lindquist, Coastal Consultant, San Diego, California. At the inception of the project, Dr. Kraus was a staff member at Texas A&M University-Corpus Christi, Corpus Christi, Texas, and Dr. Byrnes was a staff member at the Center for Coastal Studies, Louisiana State University, Baton Rouge, Louisiana.

At the time of publication of this report, COL Robin R. Cababa, EN, was Acting Director of WES.

Summary

More than 300 plaintiffs owning property along the Atlantic Ocean coast of Brevard County, Florida, are suing the United States for the alleged taking of their property through beach and dune erosion attributed to construction, operation, and maintenance of Canaveral Harbor. This Harbor was constructed from 1950 to 1954 on an uninterrupted segment of barrier beach. In this report, coastal-sediment processes along the coast are identified and analyzed, with emphasis on quantifying shoreline change, bathymetric change, and storm-induced beach change. Analysis is focused on two property owners, Don and Gale Applegate, and Noro and Company, Inc., who were the test plaintiffs selected by the Court. The Applegates purchased their property on August 12, 1981, and still own it. Noro purchased on September 8, 1986,[1] and sold on September 11, 1996. In this report, estimates of beach and dune erosion, if any, were calculated from time of purchase to December 8, 1997 (representing the present), for Applegate, and from time of purchase to September 11, 1996 (the sale date), for Noro. Appendices contain detailed technical material to supplement discussion and findings contained in the main body of this report.

Long-term, regional beach change was evaluated by analysis of survey data on shoreline position, bathymetry, and beach profiles taken through time. Data sets accessed originated from the Florida Department of Environmental Protection (FDEP), the National Ocean Service, and the U.S. Army Corps of Engineers (USACE) and were supplemented with specific data collection performed for this study. The analysis was conducted within a Geographic Information System framework that included estimation of errors in the data and analysis procedures. Erosion of the beaches and dunes, principally attributed to storm impacts, was estimated at the properties of the two test plaintiffs by compiling storm data and calculating beach and dune change with a numerical model.

Conclusions of this study are as follows:

1. The sand[2] placed on Brevard County's beaches by the USACE in 1974/75 extended the shoreline seaward of the 1948 (pre-Harbor) shoreline position and seaward of the September 1972 (pre-fill) shoreline position. The 1974/75 beach fill more than compensated for beach erosion that had occurred since the Harbor was constructed. The erosion-impact zone induced by the Harbor that was present on the (natural) beach prior to beach-fill placement

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[1] These plaintiffs claim the purchase occurred in September 1983, but a copy of the deed indicates that Noreen and K. Edward Jaynes, General Partners of Noro and Company, purchased the Noro property on September 8, 1986, and then sold the property to Sandra Daniels on September 11, 1996.

[2] This sand was placed as part of disposal operations during deepening of the Canaveral Harbor entrance channel and construction of the Trident turning basin and access channel. Although technically not considered a beach fill, because authorization of the project and the primary objective concerned navigation and disposal of dredged sediments, hereafter the material will be referred to as beach fill or fill for convenience and simplicity of discussion.

was determined to have extended approximately 7,000 ft south of the south jetty. The fill was placed on the beach from the Harbor's south jetty and extended south approximately 10,500 ft. The fill compensated for preexisting erosion over the distance of 7,000 ft, as well as nourished previously accreting areas that are located beyond 7,000 ft south of Canaveral Harbor.

2. The beach in the 7,000-ft erosion-impact zone covered by the fill has experienced erosion since 1974/75. The volume of sand placed on the beaches south of the Harbor in 1974/75, and subsequent smaller fills and nearshore placements in the 1990s, has been effective at maintaining the shoreline seaward of its September 1972 pre-fill position. Nearly all impacts (beach erosion and shoreline recession) caused by the Harbor relative to pre-fill conditions, have been mitigated by placement of sand just south of the entrance channel.

3. Erosion that developed since the USACE beach fill in 1974/75 extends approximately 17,000 ft south of Canaveral Harbor, an increase of about 10,000 ft relative to the southern terminus of the erosion-impact zone that had occurred along the pre-fill (natural) beach. The increased distance of erosion is attributed to adjustments in the beach fill resulting from geometric differences (equilibration of beach slope and spreading loss associated with beach fills) and, possibly, grain-size differences between the natural beach and the engineered beach.

4. Sand-bypassing rates were determined through analysis of long-term sediment transport processes by comparing pre- and post-Harbor bathymetric surveys. Sand bypassing can mitigate or eliminate downdrift beach erosion caused by Canaveral Harbor. Net longshore transport rates were calculated for the vicinity of the Harbor. The volume of sand deposited along the beach north of the Harbor prior to its construction was subtracted from the volume of sand that accumulated in the entrance channel and deposited north of the Harbor after its construction, yielding an estimated sand-bypassing rate.

   Based on analysis of bathymetric data spanning 65 years, the net sand transport rate near the north jetty was calculated as 308,000 cubic yards per year (cy/year). The associated sand-bypassing rate was calculated as 155,000 cy/year (taking into account the natural sand-deposition rate prior to Harbor construction). Between 1972 and 1997, the USACE placed about 4.0 million cy (Mcy) of sand on the beaches within 17,000 ft south of Canaveral Harbor, and the shoreline to at least 42,000 ft south of the Harbor experienced net advance. Therefore, the calculated volume of sand bypassing (155,000 cy/year x 25 years = 3.9 Mcy) nearly balances the sediment added to the beach by the USACE between 1972 and 1997.

5. The conclusions listed below are based upon analysis of FDEP and USACE beach-profile data available at locations adjacent to the properties of the two test plaintiffs, supplemented by numerical modeling of storm-induced beach erosion. Main conclusions are as follows:

   a. **Applegate Property.** From August 12, 1981 (time of purchase), to December 8, 1997 (representing the present), the beach eroded and the shoreline receded. At least 95% of sand eroded from the beach fronting the Applegate property was removed from material placed during the 1974/75 USACE beach fill. The natural beach adjacent to the property prior to fill placement just recently began to erode (as shown on the December 8, 1997, beach profile at R-7). From August 12, 1981, to December 8, 1997, the mean high water (MHW) shoreline receded 216 ±7 ft, and the beach eroded 8,500 cy, as determined from beach-profile surveys. These values can be compared with calculation results from storm-induced beach erosion modeling of the cumulative impacts of three of several storms that occurred within this time period. The modeling calculations gave approximately 70 ft of recession and a volume loss attributable to storms of (at least) 3,600 cy. Numerical calculations of storm-induced beach change indicate that **at least 42±21% of the net erosion that has occurred since the time of purchase can be associated with the removal of sand from the beach by severe storms**.

   b. **Noro Property.** From September 8, 1986 (time of purchase), to September 11, 1996 (representing the time of sale), the MHW shoreline receded 9 ±7 ft, and 80 cy of material were eroded from the beach fronting the Noro property. These small changes are within variability associated with seasonal beach change and probably do not reflect a trend. Numerical calculations of storm-induced beach erosion at the Noro property indicate that **all net change in sand volume on the upper beach and the dune face was caused by storms.** Storms are deduced to be the dominant force producing beach and dune change at the Noro property and not blockage of longshore sand transport by Canaveral Harbor.

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1. Introduction

On December 4, 1992, more than 300 plaintiffs owning properties along approximately 33 miles of shoreline in Brevard County, Florida, filed a lawsuit against the Unites States Government claiming in excess of $100 million in damages allegedly arising from beach erosion.[3] Plaintiffs attribute the erosion to the construction, operation, and maintenance of Canaveral Harbor. Specifically, plaintiffs claim that the Government has physically taken their property above mean high water (MHW) (Tidal datums and associated terminology are discussed in Chapter 2). Plaintiffs claim 13.6 million cubic yards (Mcy) of erosion over a total of 6.45 miles of private property, along approximately 33 miles of shoreline, is attributed solely to the Harbor, constructed over the period 1950 to 1954. Inland and back-bay construction commenced in June 1950. However, it was not until October 1951 that the entrance was cut through the Barrier Island and began interacting with the existing coastal processes. Therefore, in this report we will refer to Harbor construction from (October) 1951 to 1954. Most of the material, 11.9 Mcy, is claimed to have been lost between the south jetty of Canaveral Harbor and Patrick Air Force Base (AFB). This report[4] presents an analysis of coastal processes and beach response to the Harbor along the site of the plaintiffs' properties and determines responsibility of the United States for alleged erosion at the properties of the two test plaintiffs.

1.1. Report Overview

Chapter 1 contains a general introduction and background to the lawsuit and provides a summary of the hypotheses and conclusions for this study. Chapter 2 describes the study site, relevant coastal processes, and pertinent regulatory issues. Chapter 3 is an assessment describing key data sources, analysis, results, and interpretation of regional shoreline movement, beach and offshore volume change, and storm-induced beach and dune erosion along the coast of Brevard County. Chapter 4 focuses on calculation of MHW shoreline-position change and beach volume change at the properties of the two test plaintiffs, Applegate and Noro. Calculation and interpretation of changes at the properties of the two test plaintiffs are a central objective of this study. Chapter 5 summarizes the analyses and presents conclusions.

The appendices contain detailed documentation and background information developed in this study. Appendix A lists the references cited in this report. Appendix B contains the Joint Protocol developed by the defense Expert-Witness Team and the plaintiff Expert-Witness Team

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3 Plaintiffs claimed they were entitled to damages back to 1951 (Harbor construction) that occurred to property prior to their ownership. This claim represents the bulk of the erosion losses. Plaintiffs claimed 8.8 Mcy of sand loss prior to ownership. After ownership, plaintiffs claimed a loss of 4.8 Mcy of sand from the beaches. By order dated March 9, 1996, the court ruled that all claims were to be calculated for period of ownership only.

4 In parallel with and subsequent to preparation of this report, USACE beach-profile survey data and other materials were identified and compiled. These data are contained in Appendix F.

for determining losses at properties. Appendix C contains a compilation of major storms that have impacted the coast of Brevard County. Photographic documentation of the present and past condition of the beach is contained in Appendix D. Appendix E contains plots of time series of water level, wave height, and wave period for three storms selected to examine storm-induced beach erosion at the properties of the two test plaintiffs. Appendix E also lists the extreme water levels at Fernandina, Florida, and Mayport, Florida. Appendix F documents the background of the Federal navigation project at Canaveral Harbor and the Federal shore-protection project for Brevard County, Florida.

1.2. Plaintiffs

Figure 1-1 displays the number of plaintiffs by year of purchase for each respective property. At the earliest dates, one plaintiff purchased on May 8, 1951 (Eberwein, Plaintiff No. 8), and another plaintiff purchased on the combined dates of August 11, 1950, and June 26, 1952 (McLeod, G. M. Trust, D/B/A Winslow Beach Gardens Apartments, Plaintiff No. 112). Approximately 90% of the plaintiffs purchased their property since 1972. Specifically, 2% were purchased from 1950 to 1959, 6% from 1960 to 1969, 22% from 1970 to 1979, 45% from 1980 to 1989, and 25% from 1990 to 1995.

In the course of Court proceedings, two test plaintiffs were selected for determining the Government's liability and establishing methodologies for assessing damages. The test plaintiffs are (1) (Don and Gale) Applegate (Plaintiff No. 1, 615 Washington Avenue, City of Cape Canaveral, FL 32920) and (2) Noro and Co., Inc., (Plaintiff No. 294, Pelican Landing Resort 1201 S. Atlantic Avenue, Cocoa Beach, FL 32931). The two test plaintiffs will be referred to as "Applegate" and "Noro," respectively, in this report. These properties and their beach setting, including shoreline change and beach-volume change, are described in Chapter 4 (with additional photographs contained in Appendix D).

The Applegates purchased on August 12, 1981, and, until recently, a two-story family residence (that was uninhabited and in disrepair for several years) was located on this property.[5] Figure 1-2 is a photograph of the Applegate property and the protective rubble and structures that

[5] On January 23, 1997, the City of Cape Canaveral Building Inspector and a City-contracted engineer conducted a site inspection of the Applegate property. The City issued a Notice of Unsafe Structure on February 2, 1997, which Mr. Applegate appealed at the City of Cape Canaveral Construction Board of Adjustments and Appeals. The Board denied the appeal on May 8, 1997, and ordered Mr. Applegate to come into compliance by June 9, 1997. Because Mr. Applegate did not take any action to fix or remove the structure by June 9, 1997, the City issued a request for demolition on July 14, 1997. On July 31, 1997, the City of Cape Canaveral issued a demolition permit to Mr. Applegate for removal of the structure. The City of Cape Canaveral Building Inspector conducted an inspection of the property on September 26, 1997, and found that portions of the structure still remained, including large parts of the foundation and the slab (See Figures 4-3 and 4-4). The rubble mound seaward of the structure was not removed and, on November 19, 1997, the FDEP issued a letter to Mr. Applegate requesting removal of the rubble on the seaward side of the property in accordance with Chapter 161.061, F.S. The FDEP and the City of Cape Canaveral issued permits, and the work was completed on March 7, 1998. Presently, there are no structures or rubble on the Applegate property.

existed in May 1996. Plaintiffs claim that 6,790 cy of dune and bluff at the Applegate property were lost since time of purchase and claim in excess of $150,000 in property damages.

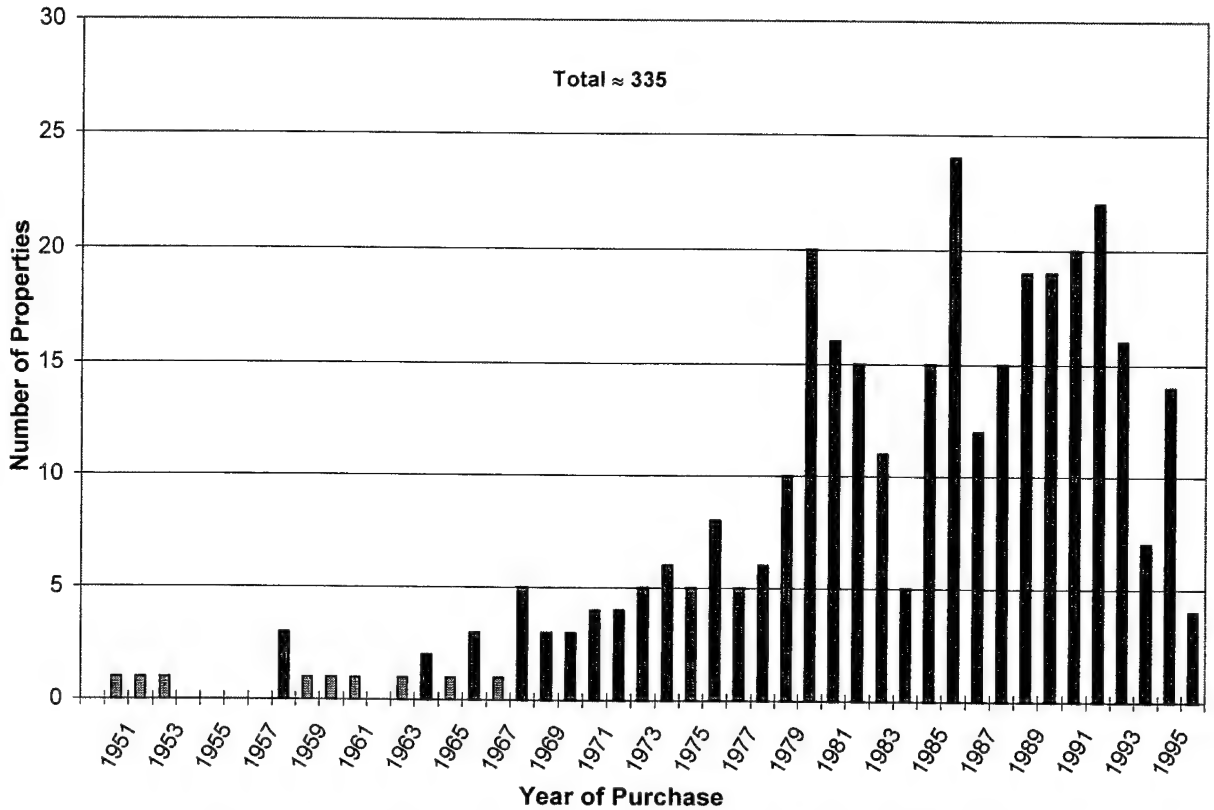

Figure 1-1. Number of plaintiffs' properties according to purchase date.
(Multiple properties purchased by one plaintiff are counted separately. Properties owned by municipalities are not included.)

The Noro property was purchased on September 8, 1986,[6] and the structure on it is a two-story motel called the Pelican Landing Resort (Noro sold this property on September 11, 1996). The Noro property is fronted by stone rubble, geotextile sandbags, and remnants of a wooden bulkhead as indicated in the photograph in Figure 1-3 taken in May 1996. Plaintiffs claim that 4,092 cy of dune and bluff had eroded from the property since September 1983 and claim in excess of $88,500 in property damages (See footnote 6).

[6] These plaintiffs claim the purchase occurred in September 1983, but a copy of the deed indicates that Noreen and K. Edward Jaynes, General Partners of Noro and Company, purchased the Noro property on September 8, 1986, and then sold the property to Sandra Daniels on September 11, 1996.

Figure 1-2. Applegate property viewed from the north, May 9, 1996. Note location of neighboring house to landward side relative to Applegate structure (source: N. C. Kraus).

Figure 1-3. Noro and Co. property, May 9, 1996, showing the deteriorated wooden bulkhead and sandbags, as well as storm erosion at the dune face (source: N. C. Kraus).

1.3. Study Hypotheses and Main Conclusions

This section summarizes the main study conclusions. The material is intended to serve as a guide through the substantial detailed discussion that follows. Two hypotheses underlie this study and assessment of coastal change. First, it is assumed that longshore sediment transport predominantly controls change in the beach that is inundated under normal (day-to-day, and non-storm) tide. Longshore transport can produce either accretion or erosion, depending on the local balance of sand entering and leaving an area of the beach.[7] The Harbor entrance is a complete littoral barrier and alters longshore sediment transport in its vicinity. Second, erosion of the upper beach (above the elevation reached by normal tide) and dune is caused primarily by storms in a cross-shore sediment transport process unrelated to the Harbor. These two processes, longshore transport and cross-shore transport, are depicted in Figure 1-4.

Changes in shoreline position and beach volume through time at the properties of the two test plaintiffs were calculated from beach-profile survey measurements. Additionally, storm impacts were estimated with a numerical model to substantiate and interpret conclusions drawn from the measurements. Main conclusions are as follows:

1.3.1. Applegate Property

From August 12, 1981 (time of purchase), to December 8, 1997 (representing the present), the beach eroded and the shoreline receded at the Applegate property. The sand eroded from the beach fronting the Applegate property was removed from material placed during the 1974/75 U.S. Army Corps of Engineers (USACE) beach fill. The natural beach north and adjacent to the property prior to fill placement just recently began to erode (as shown on the December 8, 1997, beach profile at R-7). From August 12, 1981, to December 8, 1997, the MHW shoreline receded

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7 Analysis in this report makes a distinction between the morphological features of the beach and the dune. For most discussion, unless otherwise qualified, the word beach refers to the region of dynamic boundaries extending landward from the edge of the water to the approximate 8-ft elevation NGVD. Qualitatively, the beach is where one can walk or place a blanket to sunbathe. The dune extends upward from the back beach with a near-vertical face to an elevation of approximately 10-15 ft NGVD. Daily, sediment is transported along and across the beach by water and wind, according to the level of the ordinary tide, wave conditions, and wind velocity. In contrast, the strong sediment-transporting forces of waves and currents only reach the dune when the water level is elevated during a storm or, depending on width of the beach, during a very high tide. Sediment is removed from a dune if waves and currents act upon it. As sand is removed from the dune and enters the water, it can move both alongshore and across shore.

Longshore sand transport refers to the movement of sand along the coast, parallel to the shoreline. On the Brevard County coast, daily longshore sand movement is either to the north or to the south. Erosion and accretion by longshore sand transport is a continual process associated with currents produced by incident breaking waves. Changes in beach shape and shoreline position associated with longshore sand transport tend to be gradual in the sense that the change typically cannot be observed in a day. Change in beach shape is a long-term, gradual process.

Cross-shore sand transport refers to the movement of sand perpendicular to the coast as either onshore or offshore. Under the milder waves of summer and the normal or small storms of winter, the beach accretes and erodes with a seasonal pattern. For strong storms, those with high water levels (storm surge) and higher waves of longer wave period, erosion by cross-shore transport is a short-term or event-driven process occurring over a matter of hours or days. Significant erosion can occur on a wave by wave basis during extreme events with high water levels that allow waves to attack directly against the dune. Under such storms, the dune face recedes as the dune erodes.

216 ±7 ft, and the beach eroded approximately 8,500 cy, as determined from beach-profile surveys. These values can be compared with calculation results from storm-induced beach erosion modeling of the cumulative impacts of only three major storms that occurred within this time period.[8] The modeling calculations gave approximately 70 ft of recession and a sand volume loss attributable to storms of 3,600 cy. Therefore, numerical model calculations of storm-induced beach change indicate that at least 42±21% of the net erosion that has occurred at the Applegate property since the time of purchase can be associated with the impact of severe storms.

1.3.2. Noro Property

From September 8, 1986 (time of purchase), to September 11, 1996 (time of sale), the MHW shoreline receded 9 ±7 ft, and 80 cy of material were eroded from the beach fronting the Noro property. These small changes are within variability associated with seasonal beach change and probably do not reflect a trend. Numerical calculations of storm-induced beach erosion at the Noro property indicate that all net change in volume on the upper beach and dune face was caused by storms. Storms are deduced to be the dominant force producing upper-beach and dune change at the Noro property and not blockage of longshore sand transport by Canaveral Harbor.

[8] Other storms such as Tropical Storm Erin (7/1995), Tropical Storm Jerry (8/1995), and Hurricane Fran (9/1996) also are documented as erosional to Brevard County beaches.

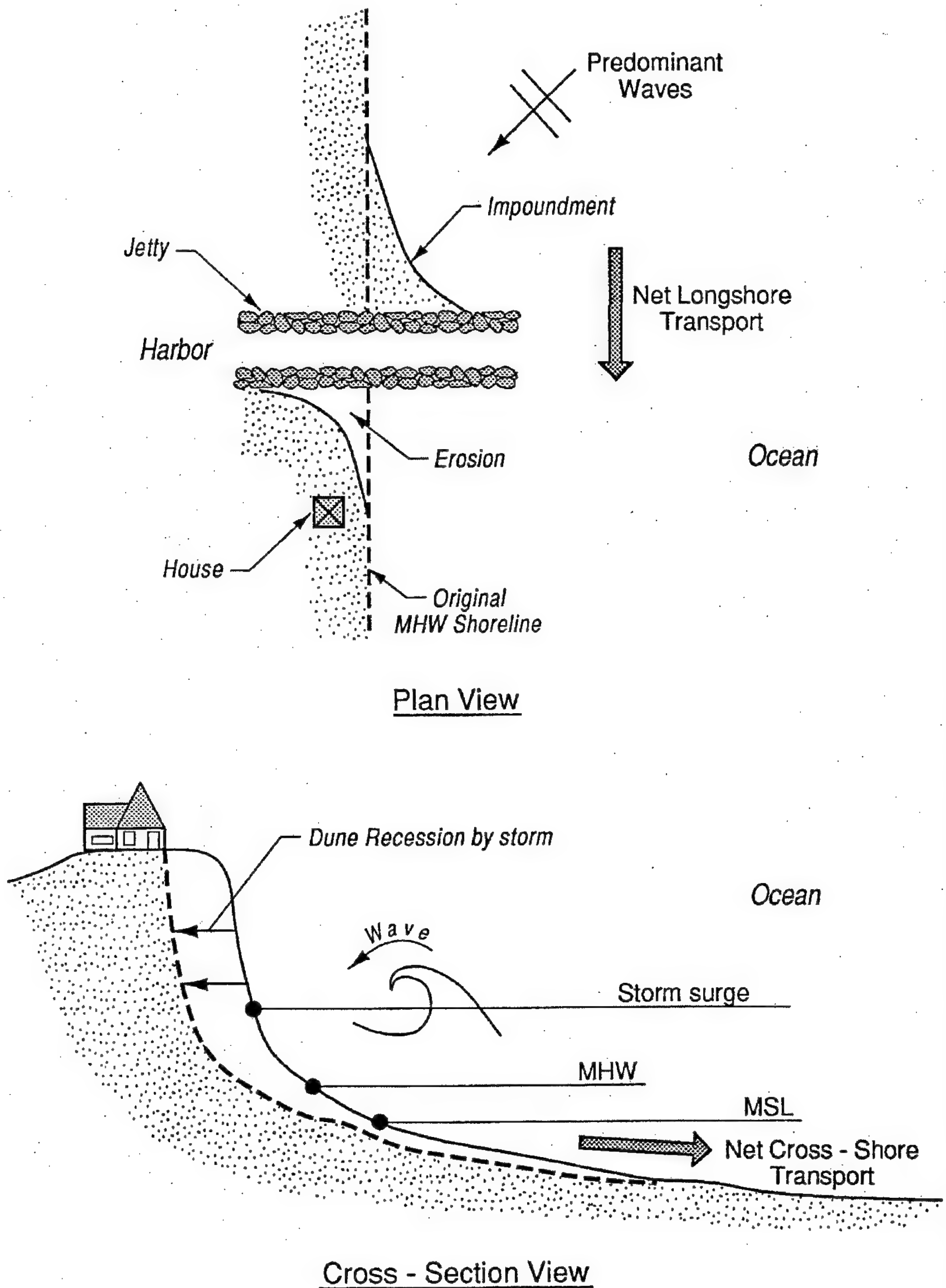

Figure 1-4. Schematic depicting typical responses to longshore and cross-shore sediment transport.

2. Background

This chapter gives an overview of the study site. Material covered includes the physical setting, natural coastal features and coastal engineering activities, and the locations of the properties of the test plaintiffs. A chronology of selected major activities and storms documented for the site is given, and the chapter concludes with a discussion of regulatory boundaries, reference datums, and shoreline definitions.

2.1. Study Site

The plaintiffs own property along the Atlantic Ocean coast of Brevard County, in northern Florida. Figure 2-1 is a site map showing the locations of the properties of the two test plaintiffs. Brevard County meets Volusia County about 31 miles north of Canaveral Harbor.[9] To the south, Brevard County meets Indian River County at Sebastian Inlet. Plaintiffs' properties extend 33 miles south along the sand beach from the south jetty of Canaveral Harbor to the north jetty of Sebastian Inlet, a reach of approximately 41 miles. The northern reach of this beach is sheltered from northeast waves by Cape Canaveral and the Canaveral Shoals. Banana River Lagoon backs the peninsula to the north and merges with Indian River Lagoon to the south, through which the Intracoastal Waterway runs. From north to south, main beach segments are (City of) Canaveral Beach, Cocoa Beach, Patrick AFB, Satellite Beach, Indialantic Beach, Melbourne Beach, and Melbourne Shores.

Table 2-1 is a chronology of selected major activities and storms pertinent to this study and associated beaches. It lists Harbor dredging, beach nourishment, major storms, establishment of the erosion-control line (ECL) and the Coastal Construction Control Line (CCCL) (regulatory boundaries are discussed in Section 2-3), and purchase dates of the two test plaintiffs.

The predominant (net) direction of longshore sand movement along the Brevard County coast is from north to south. The southward average annual longshore transport was estimated to be 350,000 cy by the USACE (Senate Document 140, 1962). The southward transport is presently estimated to be 308,000 cy/year[10] just north of the Harbor entrance channel. The magnitude of

[9] Federal authorization (River and Harbor Act of March 2, 1945) refers to the project of cutting the harbor as "Canaveral Harbor" (Federal Navigation Project). In 1953, the State of Florida established the Canaveral Port Authority and Port District, replacing a previously created political entity, the Port District, which had been created to lobby the Federal Government for authorization of the Harbor. On maps, the Canaveral-Harbor complex is denoted as "Port Canaveral." Canaveral Harbor consists of Port Canaveral and the Trident (submarine) Turning Basin, and it is bordered to the north by Cape Canaveral AFB. The ocean entrance channel is maintained by dredging to a depth of 46 ft mean low water. The west side of the Harbor connects to the Banana River Lagoon through a navigation lock that is normally closed, so tidal currents in the entrance and Harbor are weak.

[10] The magnitude and direction of longshore sand transport are seasonal. Along the study coast, in winter the transport is directed predominantly to the south, whereas in summer it is directed predominantly to the north. In most years, the net annual transport is to the south. The longshore transport rate is not constant, but varies daily, seasonally, and annually depending on weather patterns; number, direction, and types of storms; water level; and other factors.

longshore sand transport in the vicinity of the Harbor is discussed in Chapter 3. Cape Canaveral and its shoals provide substantial sheltering of waves incident from the north to the area of Canaveral Harbor, resulting in variable sand-transport rates alongshore and producing a concave shore. The Harbor jetties block sand that is moving alongshore, and the deep navigation channel also traps this sand. Consequently, accretion along the updrift beach (north of the north jetty at the study site) has accelerated, and the downdrift beach directly adjacent to the Harbor has eroded.

2.2. Canaveral Harbor

The 1945 Rivers and Harbors Act (Public Law 79-14) authorized construction of the entrance channel, jetties, turning basin, and canal at Canaveral Harbor. The Harbor entrance was constructed between 1951 and 1954. The project was modified by the 1962 Rivers and Harbors Act (Public Law 87-874) to include construction and operation of a sand-bypassing plant. The purpose of the sand-bypassing plant was, in combined use with conventional dredging, to maintain the navigation project entrance channel. A secondary purpose of the plant was to nourish the beach directly south of the south jetty by restoring an estimated 90 % of the southward annual littoral drift.

In 1993, the USACE estimated that 636,000 cy would need to be dredged once every 6 years. In 1994, the USACE Chief of Engineers modified the sand-transfer feature of the project by approving construction of sand bypassing by conventional dredging in lieu of a fixed plant. Since 1965, Federal, State, and local interests have placed 6.3 Mcy on the beaches south of Canaveral Harbor. The most significant beach fill was conducted in 1974 and 1975 (Refer to Appendix F, Table F-2 for a complete list of beach fills). At that time, 2.8 Mcy of sand were placed on a 10,500-ft-long section of beach directly south of the Canaveral Harbor entrance channel. This area of beach fill extended from the south Harbor jetty to Monument R-11 (Pierce Avenue).

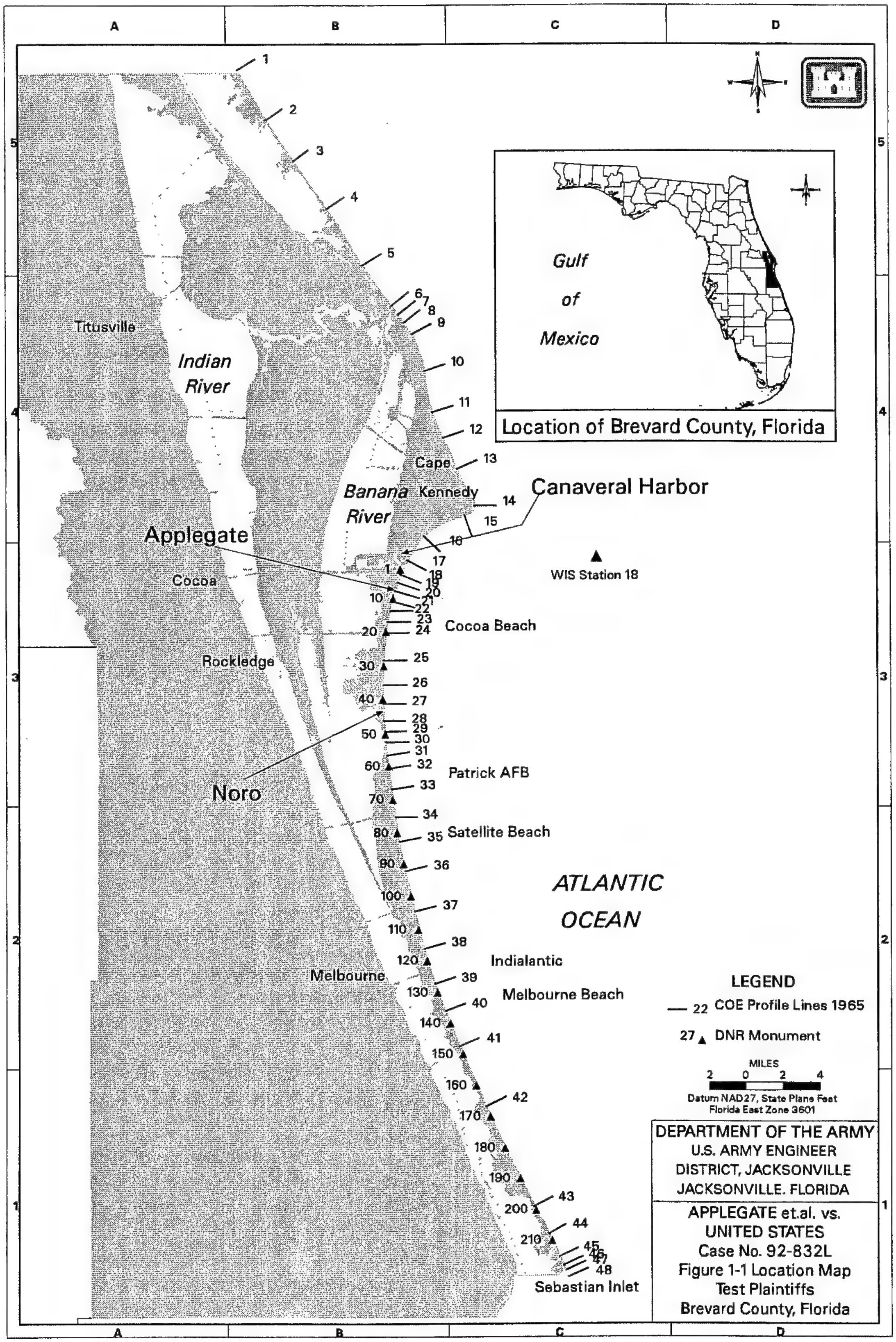

Figure 2-1. Location map for the study site

Table 2-1. Chronology of major activities and natural events at study site.		
Year	**Location**	**Activity**
06/1950	Canaveral Harbor	• Harbor construction began
10/1951	Canaveral Harbor	• Cut through barrier island
10/1952	---	• Severe northeaster
09/1954	Canaveral Harbor	• Jetties and Harbor construction complete
1960 (approx.)	305 ft S of R-7	• Applegate family constructed a single-family residential structure Within a few years they placed armoring seaward of the dwelling
1960	---	• **Three Tropical cyclones and one Northeaster**
03/1962	---	• **Ash Wednesday Northeaster**
1965	R-2 to R-4	• 120,000 cy beach placement; Federal Navigation Project
03-09/1972	R-2 to R-4	• 200,000 cy beach placement; Federal Navigation Project
1972-1974	---	• FEMA identifies Brevard Co. Coastal High Haz. Areas Flood Zones
01/1974	South Jetty to R-16	• ECL was established from south jetty to Young Avenue
10/1974	305 ft S of R-7	• Portion of Applegate home lost to tropical depress. on Oct. 6, 1974
12/1974	Brevard County	• Cabinet approves CCCL
04/1974-03/1975	South Jetty to R-11	• 2.77 Mcy beach restoration/disposal; Federal Shore Protection Project and Federal (Navy) Trident new work
11/1979	---	• **Hurricane David struck the east coast of Florida**
10/1980-01/1981	R-122 to R-135	• 540,000 cy beach restoration at Indialantic and Melbourne Beach. Federal Shore Protection Project
08/1981	305 ft S of R-7	• Don Applegate (Plaintiff #1) purchased property from his mother
11/1984	---	• **The destructive Thanksgiving Day northeaster occurred**
03/1986	Brevard County	• Revised CCCL Approved by the Florida Cabinet
09/1986	395 ft S of R-43	• Noro (Plaintiff #294) purchased property
1986	---	• **October and December Northeast storms**
03/1989	---	• **Extreme Northeast storm**
06-08/1992	R-28 to R-31	• 229,000 cy nearshore placement; Federal Navigation Project
07-11/1993	R-28 to R-31	• 180,410 cy nearshore placement; Federal Navigation Project
02-04/1994 10-11/1994	R-5 to R-11 R-28 to R-31	• 100,000 cy local beach nourishment; cosponsors were the City of Cocoa Beach and Port Authority • 161,160 cy nearshore placement; Federal Navigation Project
11/94	---	• **Tropical Storm Gordon**
07/1995	---	• **Tropical Storm Erin**
01-05/1995 08-12/1995	R-0 to R-8 R- 28 to R-31	• 831,642 cy beach placement; Federal Navigation Project • 322,990 cy nearshore placement; Federal Navigation Project
02-03/1996	R-34 to R-38	• 40,000 cy local beach nourishment; cosponsors were the City and Port Authority
09/1996	---	• Noro sold their property
1980-1996	R-53 to R-75	• 792,698 cy placed on Patrick AFB; ten placements total

- Total volume of sand placed within the first 17,000-ft zone south of the Harbor is approximately 4 Mcy.
- Total volume of sand placed on or in the nearshore of Brevard County beaches is approximately 5.5 Mcy (not including the 792,698 cy placed on the beach along Patrick AFB).

Numerous analyses of coastal processes in the Brevard County have been conducted since construction of Canaveral Harbor. These studies arrived at various estimates of longshore sediment transport rates. In 1962, the USACE estimated that the southward (net) littoral drift was 350,000 cy/year. The Canaveral Harbor General Design Memorandum (USACE 1987) described a sand-bypassing system that would bypass 106,000 cy/year. That plan was revised in the corresponding General Re-evaluation Report (USACE 1992) to sand tighten and bypass 636,000 cy every 6 years (i.e., 106,000 cy/year) on the beaches south of the Canaveral Harbor south jetty. The feasibility report for the Brevard County shore-protection project (USACE 1996) recommended that the sand bypass work be supplemented by beach restoration of 2.5 Mcy along 9.4 miles south of Canaveral Harbor. Following beach construction, the 9.4-mile-long restored beach would be periodically nourished with 516,000 cy every 6 years.[11] The Inlet Management Plan (IMP) (Bodge 1994) recommended placement of 1.03 Mcy along the shore extending 2.1 miles from the south jetty and placement of 9.6 Mcy (±2 Mcy) south of the first 2.1-mile increment to mitigate the Harbor's historical littoral impacts.

Prior to construction of Canaveral Harbor, as well as today (see Figures D-3 and D-4), the beaches and dunes along the Brevard County coast north and south of the Harbor were being eroded by storms. Although prior to Harbor construction the beach along the coast was net accretionary, some areas were eroding, such as at Patrick AFB. Erosion on this coast is evident as early as February 1948, as illustrated in Figures 2-2 and 2-3, which show ground photographs of the seawall and eroded beach at the Patrick AFB Officers Club (Monument R-57). Photographs taken in 1996 at similar sites are given in Figures 2-4 and 2-5. The Officers Club in the old photographs is fronted by a large seawall protecting the property and structure from wave attack, inundation, and erosion by persistent northeast storms in the winter months and tropical storms during the summer. The club was an early coastal structure along the study site and serves as a fixed reference for demonstrating shoreline recession that occurred on this relatively undeveloped coast prior to construction of Canaveral Harbor.

[11] The volumes of material are estimates that would be modified dependent on monitoring of the post-fill beach, because the longshore transport rate and shoreline recession are not constant.

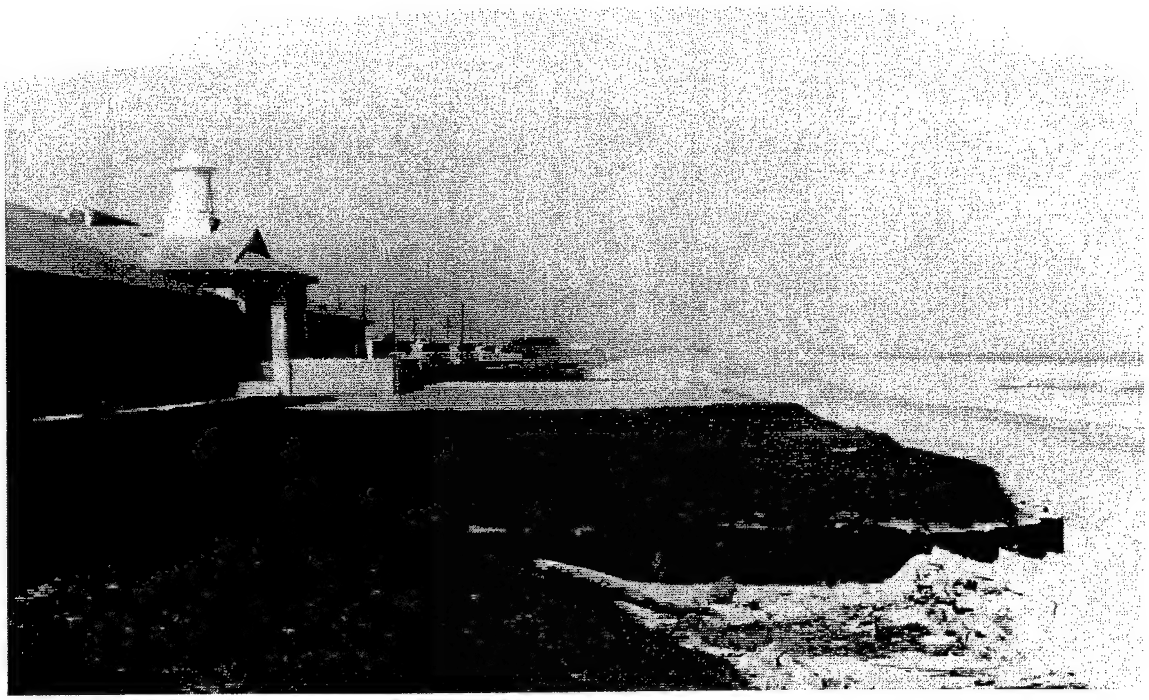

Figure 2-2. Officers Club at the Banana River Naval Air Station (Patrick AFB), February 13, 1948. Notice massive armoring on the property. The beaches of Brevard County were experiencing erosion by storms prior to the construction of Port Canaveral (source: USACE, Jacksonville District).

Figure 2-3. North end of concrete bulkhead at the Officers Club at the Banana River Naval Air Station (Patrick AFB), February 13, 1948 (source: USACE, Jacksonville District).

Figure 2-4. Northern end of concrete bulkhead at the Officers Club at Patrick AFB, February 20, 1997. Similar location as in Figures 2-2 and 2-3 (source: N. C. Kraus).

Figure 2-5. View north at Patrick AFB from Officers Club on February 20, 1997, showing storm-induced dune erosion (source: N. C. Kraus).

2.3. Relevant Coastal Processes

This section gives an overview of the coastal processes acting at the properties of the plaintiffs, focusing on those relevant to this study. Coastal processes impacting sediment transport along the beaches of Brevard County include long-term wave and current dynamics; short-term, high-energy storms; and relative sea-level rise. All these factors produce beach erosion and accretion along the Brevard County coast.

2.3.1. Sediment Transport

Longshore sand transport primarily acts on the portion of the beach below the toe of the dune, called the beach berm and foreshore. Longshore transport can advance the shoreline at a given location (accrete the beach) if more sand enters than leaves the area, or it can cause the shoreline to recede (erode the beach) if more sand leaves an area than enters. Cross-shore sand transport is primarily associated with destructive conditions (i.e., dune and/or beach erosion by storms). Sand removed from the dune and berm may then be transported out of the area of erosion by longshore transport. Also, sand removed from the dune and upper beach may be partially deposited on the lower portion of the beach, producing a seaward advance of the shoreline. The Harbor channel and jetties interrupt longshore sand transport, but the Harbor does not alter cross-shore sand transport processes. Both of these processes are water-borne transport, as summarized in Table 2-2.

Table 2-2. Comparison of longshore and storm-induced cross-shore transport processes.

Process	Longshore Sand Transport	Storm-Induced Cross-Shore Sand Transport
Dominant Forcing	Waves arriving to the coast at an oblique angle	Elevated water level and high waves with longer periods than non-storm waves
Time Scale	Months, years, decades	Hours to days for extreme events (storms and hurricanes); seasonal for regular annual change
Region of Beach Profile Impacted	Primarily beach berm, foreshore, and surf zone	Dune, berm, and foreshore
Typical Result	Shoreline recession or advance; beach erosion or accretion	Recession of the beach and dune face and loss of sand volume

2.3.2. Waves

The USACE Wave Information Study (WIS) (Hubertz et al. 1993) has performed a wave hindcast for the Atlantic Ocean coast of the United States. The hindcast covers the period 1956-1975 and involved generating waves with a numerical model with input forcing by wind and pressure fields measured in the Atlantic Ocean. WIS Station 18, located south of Cape Canaveral, is the nearest to Canaveral Harbor (Latitude 28.25 N, Longitude 80.25 W) at 22-m water depth (see Figure 1-1). The average monthly significant wave height in the 20-year

hindcast varied between a high of 1.43 m in November to a low of 0.77 m in August. Most prevalent wave periods fall in the range of 7 to 13 sec, and the predominant wave directions are NNE (expected in winter) and ESE (expected in summer). The WIS database was accessed to conduct calculations of storm-induced beach change at the properties of the two test plaintiffs.

2.3.3. Storms

The East Coast of the United States is subject to tropical cyclones (hurricanes and tropical storms) and extratropical storms (northeasters). The National Hurricane Center has compiled a record of tropical cyclone activity for the North Atlantic since 1886. In contrast, northeaster storms that have impacted Florida beaches were not well documented until around the mid-1960s. Lack of documentation is attributed to the minimal coastal development in Florida prior to the 1960s and the lack of assets that would be threatened by storms. Only the more severe regional-impacting northeast storms have been documented from the 1930s through the 1950s. Figure 2-6 displays the frequency of tropical storms per year that have been documented as erosional to Brevard County beaches. Northeasters are not included in this figure because their recorded history is not as long, and the limited record would bias discussion of storm-impact frequency before and after construction of Canaveral Harbor. The present study does document major northeasters that have struck Brevard County beaches.

The most significant erosional tropical cyclones to impact the Brevard County coast include Hurricane Greta in October 1956, Hurricane Ella in October 1962, Tropical Storm Gilda in October 1973, Hurricane David in August 1979, Tropical Storm Gordon in November 1994, and Hurricane Erin in July 1995. Known storms that have impacted the Brevard County coast and caused notable erosion are listed in Appendix C.

Some of the most significant erosional northeasters occurred in December 1932, March 1962, February 1973, November 1984 (the "Thanksgiving Day" storm), and March 1989. For the East Coast of Florida, the Thanksgiving Day storm of 1984 is considered to be the most severe extratropical storm of record, with much property damage and beach and dune erosion reported in Brevard County. Northeasters are usually associated with high waves and moderately strong winds that can persist for several days, whereas the erosive force of tropical storms usually does not persist more than a day, typically having a duration on the coast of only several hours. The stronger winds of hurricanes can drive water level much higher on the coast than can northeasters. Higher water levels allow waves to attack higher on the beach.

The frequency of cyclonic activity increased notably in the 1950s through the 1970s (Bodge and Savage 1992). Between 1930 and 1949, 15 hurricanes and tropical storms impacted the Brevard County coast (a frequency of 0.8 storms per year). For the following two decades (1950-1969), 37 cyclones impacted Brevard County (a frequency of 1.9 storms per year). The beach has less time to recover during periods with higher frequency storm occurrence, making it more

susceptible to further storm-induced erosion. The 1980s experienced minimal storm activity compared with the previous 30 years.

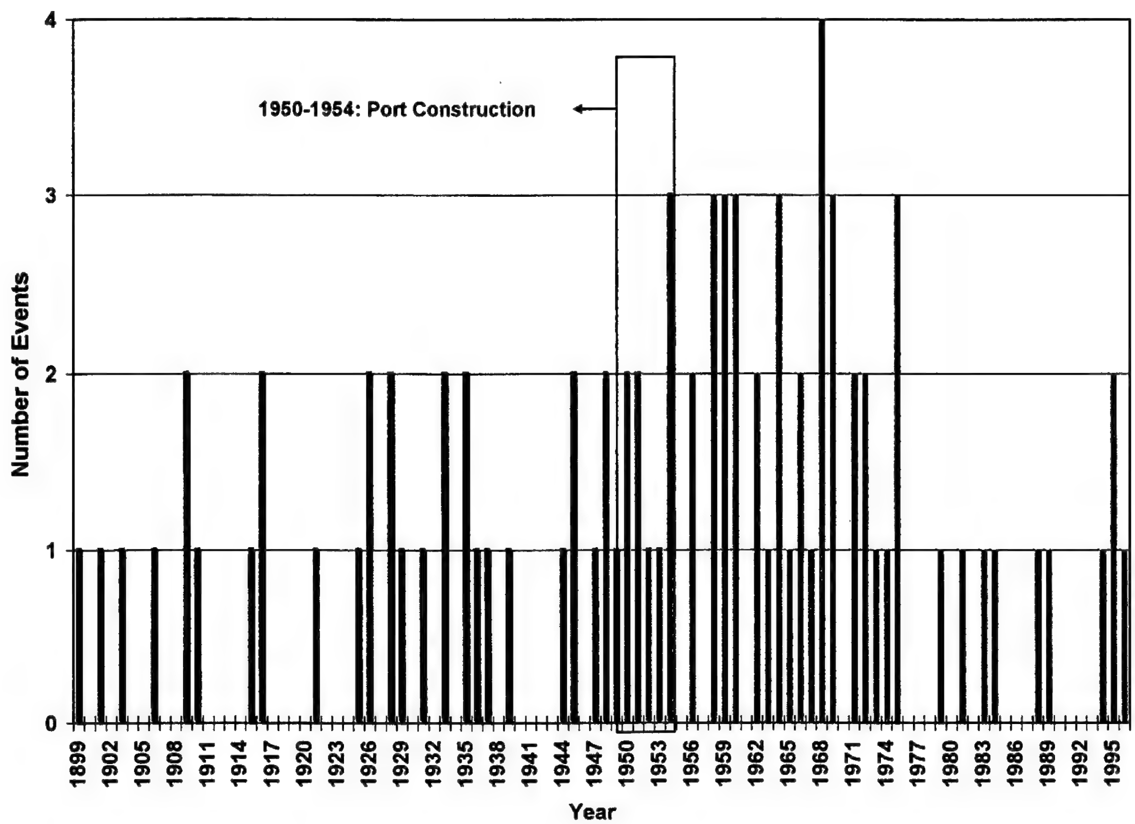

Figure 2-6. Number of tropical storms per year 1899 – 1996 documented as erosional to Brevard County beaches.

2.3.4. Sea-Level Rise

Relative sea-level rise at the project site is estimated to be on the order of 2 mm per year based on National Ocean Service (NOS) tide records at Fernandina and Mayport, Florida (Lyles, Hickman, and Debaugh 1988), the closest long-term stations to Cape Canaveral.[12] For a 50-year period, e.g., 1948 to 1998, ocean water level would have risen about 0.32 ft (4 in.) with respect to the land in coastal Brevard County. For a beach slope of 1 ft vertical to 10 ft horizontal, relative sea-level rise may account for an apparent shoreline recession of about 3 ft.

[12] Operation and maintenance of a USACE water-level gauge located at the Trident Pier has recently been assumed by the NOS as a long-term station. The Trident Pier, Port Canaveral, Florida, gauge record (872 1604) begins October 1994.

2.4. Datums and Shoreline Definitions

The position and movement of the shoreline along the project site are central to the plaintiffs' claim of taking and procedures of this study. Shoreline position can be determined by two methods, (1) with reference to a vertical datum, and (2) as an identifiable and interpreted topographic feature formed by waves and tide (e.g., the berm crest, debris line, wet/dry boundary for predicted MHW, toe of dune). In previous studies at the project site and in the present study, shoreline position has been determined by both methods. Jurisdictional and legal marine boundaries are defined in terms of tidal datums (the first method). Application of datums and measurement methods without knowledge of the errors and data inconsistencies of each method may lead to inaccurate conclusions about change in shoreline position and sand volume through time. The following section describes characteristic reference datums involved in the study.

Tidal datums as determined by the NOS at Canaveral Harbor Entrance (NOS Station 872 1608) are shown schematically in Figure 2-7. These datums are representative of the beach directly south of the Harbor. Tidal datums will change slightly with distance moved along the shore of Brevard County. The nomenclature shown in Figure 2-7 is discussed next.

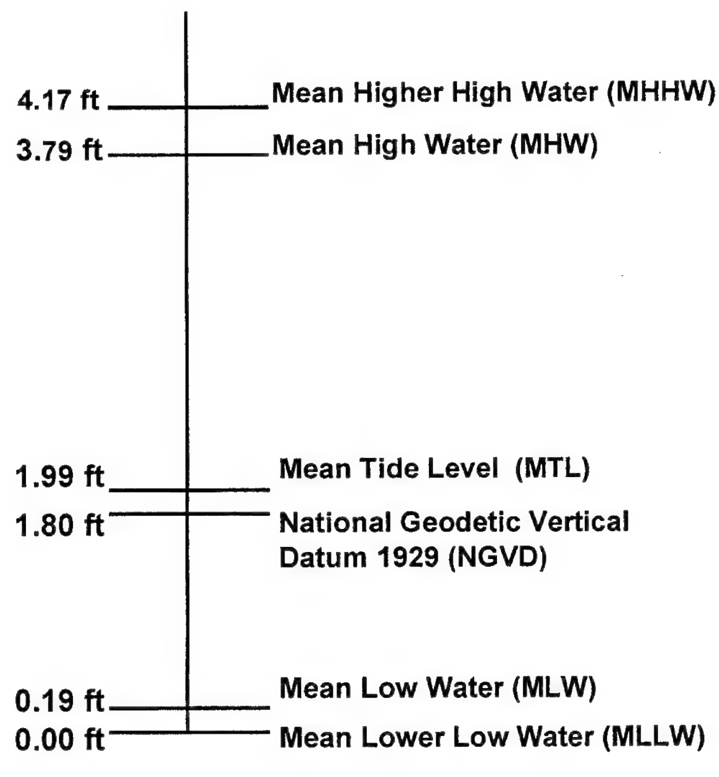

Figure 2-7. Canaveral Harbor Entrance tidal datums to gauge zero.

2.4.1. Reference Datums

A description of vertical datums pertinent to this study is presented in this section.

National Geodetic Vertical Datum. The National Geodetic Vertical Datum of 1929 (NGVD 29) is a standard geodetic (related to the shape of the earth) vertical datum used by the USACE and other agencies. NGVD 29 is a fixed vertical datum (sea level) observed at 26 primary tidal stations around the United States and Canada in 1929 (Shalowitz 1964). Therefore, in the absence of accidental or other mechanical movements of the survey benchmarks, NGVD 29 benchmarks are fixed through time and, therefore, form a convenient reference system for civil engineering works.

Construction Datums. On coastal engineering and other civil engineering projects, it is often convenient to establish a local construction datum to which project measurements can be referenced. The construction datum can itself be referenced to NGVD 29 or another datum. The USACE construction datum along the Brevard County coast lies 1.9 ft below NGVD 29.

Tidal Datums. Reference datums can be defined in terms of the phase of the tide and are then called tidal datums. Tidal datums change slowly with time because of global sea-level fluctuations and changes in local conditions, such as those associated with subsidence and water and oil extraction from the ground or sea bottom. The NOS has the Federal mission of determining and publishing tidal datums. This mission is accomplished by establishing a series of permanent benchmarks on land, called tidal stations, and measuring the water level at fixed intervals (typically, 6 min) with respect to the benchmarks. Water-surface records from short-term stations, typically deployed from 3 months to 2 years, are then referenced to long-term tidal stations with gauges that operate more than 19 years. In the 1970s, the State of Florida undertook an extensive tidal measurement program in cooperation with the NOS. This information is available for Brevard County.

NGVD 29 is sometimes confused with or referred to synonymously as MSL. The datum MSL is defined by NOS as the average of the hourly values of water-level readings of a specific 19-year tidal epoch called the National Tidal Datum Epoch (NTDE), presently 1960 to 1978. However, because many variables control water level, and because a geodetic datum represents a best-fit surface over a broad area and not to a specific area, NGVD 29 is not, in general, equal to MSL. The geodetic datum can deviate from MSL by 1 ft or more, depending on location.

The tidal datum MHW determines the boundary between State of Florida submerged bottom lands and privately held uplands. The intersection of the land and sea at the elevation of MHW is called the mean high-water line (MHWL), denoting the MHW shoreline. MHW and mean low water (MLW) are, respectively, the averages of all the high-water heights and low-water heights observed over the NTDE. The mean range of tide is the mean of the differences in height between high waters and low waters over the NTDE. A tidal datum close to the value of MSL is

mean tide level (MTL). MTL is calculated as the mean of the differences between high water and low water.

In Florida, MHW surveys to be filed with the State involve coordination with the Florida State Bureau of Survey and Mapping. The Bureau maintains a list of relations between NGVD 29, the fixed land datum, and MHW along the coast. These relations and other guidance are provided to the surveyor, who can then locate the MHWL by an accurate beach-profile survey that is connected to NGVD 29.

2.4.2. High-Water Line (HWL)

Historical data generated by the U.S. Coast and Geodetic Survey (USC&GS, predecessor organization to the present NOS) in its survey of the coast performed in the 1800s, and in coastal topographic surveys performed to present, identify a shoreline position as an interpreted HWL. The authoritative reference on the meaning and procedures of measuring the HWL is Shalowitz (1964), who was educated both as an attorney and engineer and was employed by NOS.

Quoting Shalowitz (1964, pp. 171-172), *The most important feature on a topographic survey is the high-water line. It is the line that is used on the nautical charts of the Coast Survey as the dividing line between the land and water; the line that indicates whether the coast is building out or receding...* Further, *From the standpoint of the surveyor, the high-water line is the only line of contact between land and water that is identifiable on the ground at all times and does not require the topographer being there at a specified time during the tidal cycle, or the running of levels. The high-water line can generally be closely approximated by noting the vegetation, driftwood, discoloration of rocks, or other visible signs of high tides.*

The HWL is, therefore, not the shoreline defined by MHW, as sometimes marked on charts and maps published by the NOS and the U.S. Geological Survey (USGS). Instead, it is the shoreline mapped at the time of predicted MHW, which includes meteorological effects such as setup, set down, and runup because of waves. USC&GS topographers and topographers today doing routine wide-area shoreline-position surveys (such as by Global Positioning System (GPS) techniques) refer measurements to the HWL at the time of MHW in the field.

The HWL inferred from aerial photographs might be either the instantaneous intersection of land and water at the time of MHW or the boundary between aeolian and waterborne deposits determined by visual interpretation of a discontinuity in color or geomorphology (Anders and Byrnes 1991). Mapped shoreline positions related to water level at the time photography was flown (other than MHW) may be poor estimates of the HWL and inconsistent with the historical database. Byrnes, Mc Bride, and Hiland (1991) discuss origins and treatment of various types of shoreline-position data.

2.4.3. *Comparison of Shoreline Definitions*

Figure 2-8 is a schematic depicting several common definitions of the shoreline, including the MHW intersection and the HWL. If different data sets are analyzed without conversion or reference to a common datum, then an apparent shift in shoreline position will occur, as discussed by Kraus (1997). Analysis of shoreline positions differently defined could lead to either apparent advance or recession of the shoreline. Because the MHWL is defined by a reference (vertical) datum, and the HWL is determined by interpretation of a topographic feature (such as the berm crest or foot of the dune), the methods are not directly comparable. The two shoreline positions must be related through additional analysis that can only provide an estimate of the distances between them.

Two coastal geomorphologic configurations are shown in Figure 2-8, one where a berm crest can be clearly discerned, and the other in which a berm is not apparent, requiring identification of the HWL at the foot of the dune. This figure also schematically shows the instantaneous position of the water or shoreline created by wave- and wind-induced runup, which is the periodic up and down motion of the water at the shore associated with waves and wind. Runup creates the berm by pushing sand up onto the landward edge of the foreshore, a region that is periodically inundated with rise and fall of the tide and runup. Berms are created during calm wave conditions and are removed (eroded) by storm waves if the water level rises sufficiently during the storm. The berm crest represents a relatively stable feature that characterizes the boundary between land and sea — the shoreline.

2.4.4. *Florida Coastal Jurisdictional Boundaries*

In 1972, the Florida Department of Environmental Protection (FDEP: formerly the Department of Natural Resources (DNR), which merged with the Department of Environmental Regulation (DER) in 1993 to become the FDEP), began to establish a system of profile survey monuments along all sandy beaches in the State of Florida. The monuments are benchmarks that allow consistent surveys to be made for the study and regulation of the sandy beaches of the State. Most of these monuments are denoted by the symbol "R" followed by a number. On the Atlantic coast, the R-monuments start at R-1 at the northern boundary of each county and continue consecutively (R-1, R-2, R-3, etc.) to the southern boundary within the same county.

In 1994, the USACE established a monument in Brevard County called R-0, which is located directly south of the south jetty at Canaveral Harbor. This monument aided the design and monitoring of the 1994 sand-bypassing project. The approximate locations of the FDEP R-monuments in Brevard County are shown in Figure 1-2. The location of R-0 and the other monitoring survey monuments for the sand-bypassing project are shown in Appendix F.

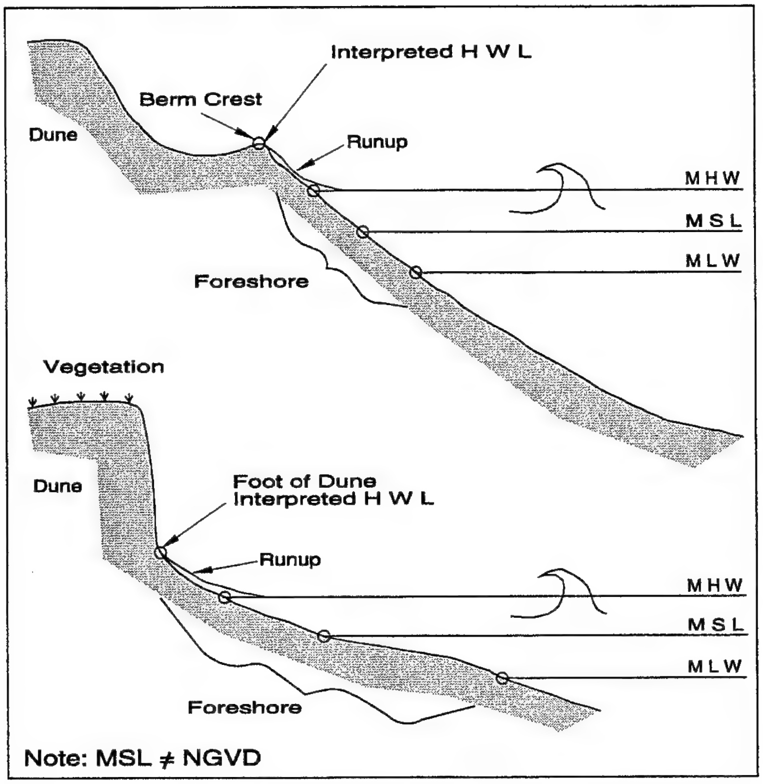

Figure 2-8. Shorelines determined by selected methods.

The monuments are located at approximately 1,000-ft intervals starting with R-0 at the south jetty of Canaveral Harbor and ending at R-219 at the southern border of the county, Sebastian Inlet. This section of the Brevard County Atlantic Ocean coast is, therefore, approximately 41 miles long and is the focus of this report. Brevard County also extends north of Canaveral Harbor to Volusia County, but this northern coastal area is Federal property (combination of the air force base, National Aeronautic Space Administration, and the Cape Canaveral National Seashore). The FDEP has no jurisdiction over Federal land, and thus no State-regulated monuments exist in this northern area. Several USACE survey monuments located throughout Brevard County have been used for studies of the Canaveral Harbor navigation project and the Brevard County shore-projection project (see Figure 1-2).

As required in Chapter 161.053, Florida Statutes (F.S.), the FDEP established a CCCL on a county basis along the sandy beaches of the State fronting the Atlantic Ocean, the Gulf of Mexico, and the Straits of Florida. The CCCL defines that portion of the beach-dune system that is subject to "severe fluctuations" based on a 100-year storm surge, storm waves, or other predictable oceanographic and meteorological conditions. The term "fluctuations" in the context of the CCCL is assumed to refer to locations of shoreline recession (beach erosion) and shoreline advance (beach accretion). The CCCL is not a setback line, but, rather, defines a jurisdictional area in which construction seaward of the CCCL is regulated. A setback line generally restricts

construction activities seaward of such line. Special siting and design considerations are necessary seaward of the CCCL to ensure the protection of the beach-dune system, proposed or existing structures, and adjacent properties, as well as the preservation of public beach access.

In 1980, Chapter 161.053, F.S. was amended by adding *any coastal construction control line that has not been updated since June 30, 1980, shall be considered a critical priority for reestablishment by the department.* The CCCL in Brevard County was reestablished in March 1986 to a more landward location that better represents the zone subject to the 100-year storm surge.

In 1987, Chapter 161.57, F.S.[13] was added by the Florida Legislature. This provision requires that purchasers of interests in real property located in coastal areas partially or totally seaward of the CCCL be apprised of the character of the regulation of the real property in such coastal areas and, in particular, that such lands are subject to frequent and severe fluctuations.

Prior to construction of a beach restoration or beach nourishment project, the State of Florida requires that an ECL be established (Chapter 161.141, F.S.). Upon the filing of a resolution of the Florida Board of Trustees of the Internal Improvement Trust Fund and the recording of the survey showing the location of the ECL (pre-Project MHWL for the area to be restored), title to all lands seaward of the ECL shall be deemed to be vested in the State by right of its sovereignty, and title to all land landward of such line shall be vested in the riparian upland owners (Chapter 161.191, F.S.).[14] *If the state, county, municipality, erosion-control district, or other governmental agency charged with the responsibility of maintaining the protected beach fails to maintain the same and as a result thereof the shoreline gradually recedes to a point or points landward of the erosion control line, the provisions of Chapter 161.191, F.S. shall cease to be operative as to the affected upland* (Chapter 161.211, F.S.).

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[13] 161.57, F.S. Coastal properties disclosure statement. (1) The Legislature finds that it is necessary to ensure that the purchasers of interests in real property located in coastal areas partially or totally seaward of the coastal construction control line as defined in S. 161.053 are fully apprised of the character of the regulation of the real property in such coastal areas and, in particular, that such lands are subject to frequent and severe fluctuations. (2) Unless otherwise waived in writing by the purchaser, at or prior to the closing of any transaction where an interest in real property located either partially or totally seaward of the coastal construction control line as defined in S 161.053 is being transferred, the seller shall provide to the purchaser an affidavit, or a survey meeting the requirements of Chapter 472, delineating the location of the coastal construction control line on the property being transferred.

[14] 161.191, F.S. Vesting of title to lands (1) Upon the filing of a copy of the board of trustees' resolution and the recording of the survey showing the location of the erosion control line and the areas of beach to be protected as provided in S. 161.181, title to all lands seaward of the erosion control line shall be deemed to be vested in the state by right of its sovereignty, and title to all lands landward of such line shall be vested in the riparian upland owners whose lands either abut the erosion control line or would have abutted the line if it had been located directly on the line of mean high water on the date the board of trustees' survey was recorded.

The ECL just south of Canaveral Harbor was approved by the Florida Board of Trustees on December 18, 1973, and a Florida DNR, Bureau of Beaches and Shores[15] (BBS) Construction Permit (BBS 73-74-4) was issued. The permit was executed by the Brevard County Board of Commissioners in Special Session on December 31, 1973. The MHWL survey to establish the ECL for the Cape Canaveral segment of the Brevard County beach erosion control project was completed on June 29, 1973 (Sheets 1-5, Folder 2 of 2, BBS 73-74-4). The ECL was set 300 ft seaward of the June 29, 1973, MHWL survey from the north limit of Port Canaveral Jetty Park south to the north line of Madison Avenue. The ECL was then tapered to the existing MHWL at the north line of Polk Avenue and followed the MHWL south to the north line of Young Avenue, a distance of 2.8 miles (Sheets 1-6, Folder 2 of 2, BBS 73-74-4).

The ECL at Indialantic and Melbourne Beach was approved by the Florida Board of Trustees on June 26, 1979. A Florida DNR Division of Beaches and Shores (DBS) construction permit (DBS 79-0009) was issued on June 18, 1979, for the Brevard County beach erosion control project segment at Indialantic and Melbourne Beach.

Approximately 4.5 Mcy of beach-quality sand were available for a beach fill from the 1974-1975 Trident work (see later descriptions of the Federal navigation and shore-protection project activity). Approximately 1 Mcy were needed to construct the Cape Canaveral segment. The remaining 3.5 Mcy were to have been placed on the beach as a cost-effective way of disposing of the material. The 4.5 Mcy, if placed uniformly along the 2.8 miles south of Canaveral Harbor, would have resulted in a 400-ft-wide construction berm. The ECL was to be placed seaward of the June 29, 1973, MHWL by 300 ft throughout the 2.8-mile project length. This location of the ECL was to allow placement of the 3.5 Mcy of Trident Fill beach disposal material in accordance with Chapter 161.141 F.S., which states in part that the ECL *shall not be fixed for beach restoration projects that result from inlet or navigation channel maintenance dredging projects.* The 1 Mcy destined for the shore-protection project were to be placed seaward of the ECL.

2.4.5. Federal Jurisdictional Boundaries

Since 1972, the Federal Emergency Management Agency (FEMA), through the National Flood Insurance Program (NFIP), has identified Coastal High Hazard Areas, termed V- (Velocity) Zones. As depicted on NFIP Flood Insurance Rate Maps (FIRMs), V-Zones are areas subject to damage by waves 3 ft or higher during the 100-year event. Zones subject to the 100-year flood with waves less than 3 ft high are labeled as A-Zones. The inland extents of the V- and A-Zones are derived from computer models that calculate the landward penetration of a storm surge that can support a breaking wave 3 ft in height.

[15] The Bureau of Beaches and Shores (BBS) was later recategorized, and thus renamed, as the Division of Beaches and Shores (DBS) within the DNR. After the FDEP was created, the Division was again changed to the Bureau of Beaches and Coastal Systems (BBCS).

In communities that participate in the NFIP, construction is allowed within the V-Zone if it complies with State and local floodplain ordinances that meet NFIP requirements. Lending institutions enforce purchase of flood insurance for buildings located in the V-Zone as a condition of obtaining Federally sponsored or insured mortgages or home-improvement loans. All parcels of land fronting the Atlantic Ocean in Brevard County are at least partially within the V-Zone and substantially or wholly within the A-Zone (FIRMs for Brevard County dated April 1989 and August 1992). The dates that communities in Brevard County were first identified as being in a flood zone by FEMA are shown in Table 2-3.

Table 2-3. Dates Brevard County communities were identified as being in a flood zone by FEMA.

Community	Identification Date
City of Cape Canaveral	Sep 1972
Canaveral Port Authority	Oct 1979
Cocoa Beach	Jun 1972
Satellite Beach	Feb 1974
Indian Harbour Beach	Jun 1972
Town of Indialantic	Aug 1972
Melbourne Beach	Nov 1972

3. Assessment of Coastal Change

This chapter describes the regional beach and nearshore response to waves and storms that occur along the coast of Brevard County, with focus on the properties of the test plaintiffs. Historical shoreline, beach profile, and bathymetry data sets are analyzed to document coastal evolution prior to and after construction of Canaveral Harbor. These data represent the primary sources of information for quantifying the impact of Harbor construction on property downdrift of the jetties. Data collected by the FDEP, the USC&GS (now NOS), and the USACE are the foundation upon which objective evaluations are made for assessing impacts at the properties of the test plaintiffs.

3.1. Data Sources

Three sources of data were analyzed for quantifying shoreline-position change that has occurred along the coast of Brevard County for the period of record (1875 to 1998). Historical shoreline data sets from the NOS and a May 1996 shoreline surveyed using GPS technology established a consistent record of continuous measurements along the coast at an interpreted HWL (Table 3-1). FDEP and USACE beach-profile survey data were analyzed to determine cross-shore change in beach shape.

Beach-profile survey data document short-term shoreline change at a 1,000-ft longshore spacing. NOS hydrographic data sets from 1929 and 1956 surveys, bounded on the landward side with the 1928 and 1948 NOS shoreline surveys, documented beach and nearshore sand volume changes prior to Harbor construction. Also, a hydrographic survey conducted for this study by the USACE (May 1996), together with the 1996 GPS shoreline survey, shows the beach and nearshore change resulting from Harbor construction.

The Canaveral Harbor entrance and jetties were constructed over the period June 1951 to September 1954 (see the chronology in Table 2-1 and Appendix F). Immediate post-construction bathymetric survey data are not available to define morphologic adjustments after construction of the north Harbor entrance jetty. As a replacement, the 1948 NOS shoreline survey provided a surrogate landward boundary of the bathymetric surface to document beach and nearshore change prior to Harbor construction. As such, the available 1929 and 1956 NOS hydrographic surveys primarily documented pre-construction adjustments in sand volume north of the Harbor.

All coastal morphology data sets contain errors that are related to measurement technique, map scale, and digital data-compilation and analysis procedures. In this study, to judge the significance of measured rates of beach and shoreline change, potential errors are quantified and compared with measurements. In considering all potential inherent errors associated with data compilation and analysis, it is recognized that these apply to each individual data set. In making comparisons of shoreline-position and bathymetric change, errors in measurement and technique

accumulate. If it is assumed that individual errors represent standard deviations, a root-mean-square (rms) approach can be applied to provide a realistic assessment of combined potential errors (Merchant 1987, Crowell, Leatherman, and Buckley 1991). In other words, if sources of error are independent, there is some cancellation of error, resulting in a reduction of combined potential errors.

Table 3-2 summarizes estimates of potential positional error for the primary data sources analyzed in this study. The rms error for 1875/79 topographic maps (T-sheets; 1:20,000 scale) is about ±50 ft, whereas the 1928 and 1948 T-sheets (1:20,000) and the 1970 topographic photomaps (TP-sheets; 1:10,000) contain about ±55 and ±27 ft of potential error, respectively. The GPS survey provided the most accurate measurement of shoreline position, with an estimated maximum rms error of ±14 ft. Table 3-3 provides a summary of maximum rms errors for available shoreline change data for the study area.

Table 3-1. Characteristics of shoreline data sources.

Date	Data Source	Comments and Map Numbers
1875/79	USC&GS Topographic Maps (1:20,000)	First shoreline surveyed with standard engineering techniques; 1875 – New Smyrna Beach to False Cape (T-sheets 1415a, 1415b, 1423); 1877 – Cape Canaveral to Cocoa Beach (T-sheets 1450a, 1450b); 1878/79 - Indialantic to Sebastian Inlet (T-sheets 1460, 1478)
April 29-30, 1928	USC&GS Topographic Maps (1:20,000)	All maps produced from interpreted aerial photography (T-sheets 4530, 4440b, 4441b, 4442b, 4554, 4555, 4556)
April 1948	USC&GS Topographic Maps (1:20,000)	All maps produced from interpreted aerial photography (T-sheets 9162, 9164, 9165, 9168, 9171, 9174, 8880, 8882, 8884)
February 1970	USC&GS Topographic Photomaps in Cooperation with State of Florida (1:10,000)	All photomaps produced from interpreted aerial photography (TP-sheets 135, 136, 138, 140, 142, 143, 145, 146, 147, 149)
May 20-22, 1996	Differential GPS Survey (1:1)	North boundary of Cape Canaveral National Seashore to Sebastian Inlet

Table 3-2. Estimates of potential error associated with shoreline position surveys.		
Traditional Engineering Field Surveys (1875/79)		
Location of rodded points Location of plane table Interpretation of high-water shoreline position at rodded points Error because of sketching between rodded points	±3 ft ±6 to 10 ft ±10 to 13 ft up to ±16 ft	
Cartographic Errors (all maps for this study)	**Map Scale**	
	1:10,000	1:20,000
Inaccurate location of control points on map relative to true field location	up to ±10 ft	up to ±20 ft
Placement of shoreline on map	±16 ft	±33 ft
Line width for representing shoreline	±10 ft	±20 ft
Digitizer error	±3 ft	±6 ft
Operator error	±3 ft	±6 ft
Aerial Surveys (1928, 1948, and 1970 shorelines)	**Map Scale**	
	1:10,000	1:20,000
Delineating high-water shoreline position	±16 ft	±33 ft
GPS Survey (1996 shoreline)		
Delineating high-water shoreline	±3 to 10 ft	
Position of measured points	±6 to 16 ft (specified); ±3 to 10 ft (field tests)	
Sources: Shalowitz 1964; Ellis 1978; Kruczynski and Lange 1990; Anders and Byrnes 1991; Crowell, Leatherman, and Buckley 1991		

Table 3-3. Maximum potential rms error for shoreline change data.

Date	1928	1948	1970	1996
1875/79	±74.5[1]	±74.5	±56.9	±52.0
	(±1.5)[2]	(±1.0)	(±0.6)	(±0.4)
1928		±78.1	±61.5	±56.9
		(±3.9)	(±1.5)	(±0.8)
1948			±61.5	±56.9
			(±2.8)	(±1.2)
1970				±30.5
				(±1.1)

1 Magnitude of potential error associated with high-water shoreline position change (ft).

2 Rate of potential error associated with high-water shoreline position change (ft/year).

3.2. Seasonal Beach Change and Variability

Beaches and dunes are dynamic morphologic features that experience substantial seasonal fluctuations and spatial variability in elevation, width, and shape. In winter, beaches commonly have low relief because energetic waves and currents remove sand from the beach face and transport it offshore. Conversely, in summer, beaches typically display constructive features formed from sand deposited on the foreshore. Typical winter and summer beach profiles are depicted schematically in Figure 3-1. In regions with relatively low rates of long-term shoreline recession, seasonal changes in shoreline position can exceed the annual recession rate by many times. Consequently, accurate representation of average beach change depends on consistent seasonal comparisons to reduce inter-annual variations. For Brevard County, inter-annual variation in shoreline position associated with seasonal change is estimated to reach ±30 ft by examination of FDEP beach-profile surveys.[16]

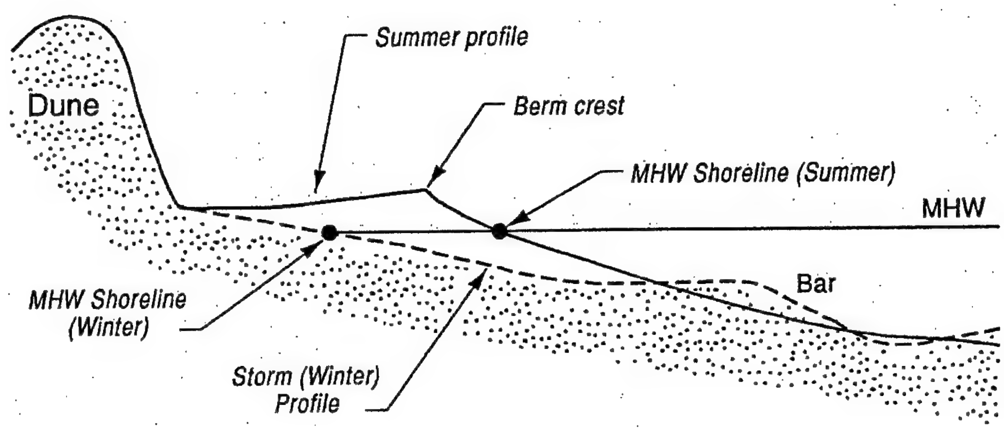

Figure 3-1. Schematic showing typical winter and summer beach profile shapes.

Another factor influencing shoreline position as determined from beach-profile survey data is the uncertainty associated with interpolating between FDEP lines (R-monuments) that are spaced approximately 800 to 1,000 ft apart. This uncertainty is of particular concern at the study site, which has mixed nourished beach and natural beach together with coastal structures. Depending on natural variation in beach and dune morphology along a coast and the influence of structures (e.g., seawalls, bulkheads, and rubble), variability in shoreline position is estimated to be as

[16] Comparison of profile shape at R-7 and R-44 (Figures 4-5 and 4-11) for winter (January 1985) and summer (August 1985) shows a 30-ft maximum seasonal change in contour position.

much as ±15 ft. Because the surveys were not performed exactly at the date of purchase of the property, additional uncertainty is introduced. Given these inconsistencies, shoreline-position variability associated with interpolation and variability along the beach is estimated to be ±30 ft.

In summary, seasonal changes and inconsistencies between purchase dates and times of available surveys must be considered for quantifying and interpreting the significance of shoreline-position change at a site, particularly as it relates to the MHW property boundary. In analyzing data from different seasons that bracket the property purchase date, one can expect variation in shoreline position on the order of ±45 ft (total rms error for combined errors from seasonal variability, interpolation between profiles, and longshore variability in the beach).

3.3. Long-Term Shoreline Change

This section describes measurements and calculations of shoreline change for two time periods, the pre-Harbor time period represented by 1877 to 1948 and the post-Harbor period represented by 1948 to 1996. These measurements are referenced to the HWL (See Chapter 2).

3.3.1. Shoreline Change prior to Harbor Construction (1877 to 1948)

The earliest shoreline surveys prior to Harbor construction include an initial field survey conducted in 1877 and aerial photographic surveys completed in April 1928 and April 1948. Although property ownership by the plaintiffs did not begin until the early 1950s, an assessment of shoreline response prior to this time is necessary to evaluate the impact of Harbor construction on beach evolution. For the periods 1877 to 1928 and 1877 to 1948, the shoreline extending from 12,000 ft north of the Harbor to approximately 35,000 ft south of the Harbor showed advance (Figure 3-2). However, the shoreline south of this point to Sebastian Inlet receded and advanced independent of the Harbor. The rate of change varies between the two time periods.

Greatest variation in beach response occurs north of the Harbor, adjacent to Cape Canaveral shoals. This area receives substantial quantities of sand from the north through southerly directed longshore transport that supplied large quantities of sand to southern beaches in Brevard County. Between 1877 and 1928, shoreline advance along beaches within 30,000 ft south of the Harbor occurred at rates ranging from approximately 0 to 8 ft/year. Although the direction of shoreline movement between 1877 and 1948 had the same trend as for the period 1877 to 1928, the magnitude of change decreased slightly within the first 7,000 ft south of the Harbor.

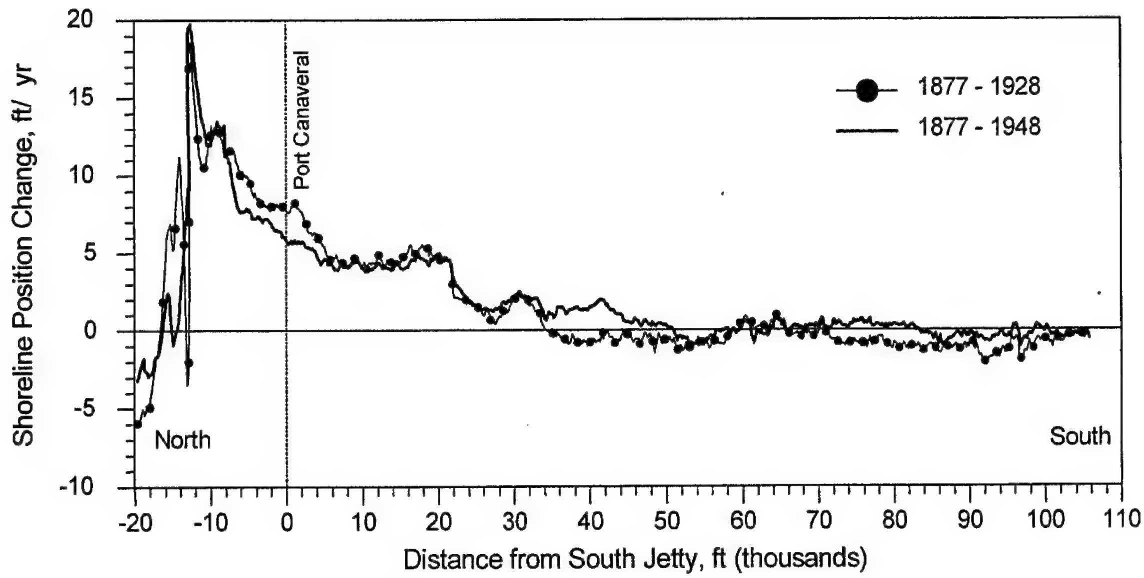

Figure 3-2. Change in historical shoreline position (HWL) prior to Harbor construction.

3.3.2. Shoreline Change after Harbor Construction (1948 to 1996)

After Harbor construction, greater shoreline advance occurred north of the Harbor because of impoundment at the north jetty. The shoreline for about 7,000 ft of coast directly south of the Harbor receded as a result of this impoundment and deposition into the entrance channel.

Change in shoreline position for the period 1948 to 1970 was evaluated using NOS data sets, which were also compiled and analyzed by the FDEP.[17] A reevaluation of the FDEP historical data set was completed in the present study as a quality control and assurance procedure because these data are central for determining alleged losses. A May 1996 GPS ground survey was also performed in this study to evaluate cumulative shoreline changes to that date, representing the "present," for regional geomorphic analysis. Figure 3-3 shows post-construction shoreline response prior to and after the beach fill in 1974/75. Between April 1948 and February 1970, downdrift shoreline recession occurred along a reach extending to about 7,000 ft south of the Harbor. For the same period, south of this 7,000-ft reach to approximately 34,000 ft south of the Harbor, the shoreline advanced about 50 ft. The change from net shoreline recession to net shoreline advance determines the boundary of Harbor-induced erosion to be located within 7,000 ft south of the jetty. South of this location, no net adverse impacts to the beach can be attributed to the Harbor for the period 1948 to 1996, because the shoreline advanced.

[17] The FDEP historical shoreline-position data from the 1948 and 1970 NOS data sets were obtained from the FDEP Internet web site at http://www.dep.state.fl.us/.

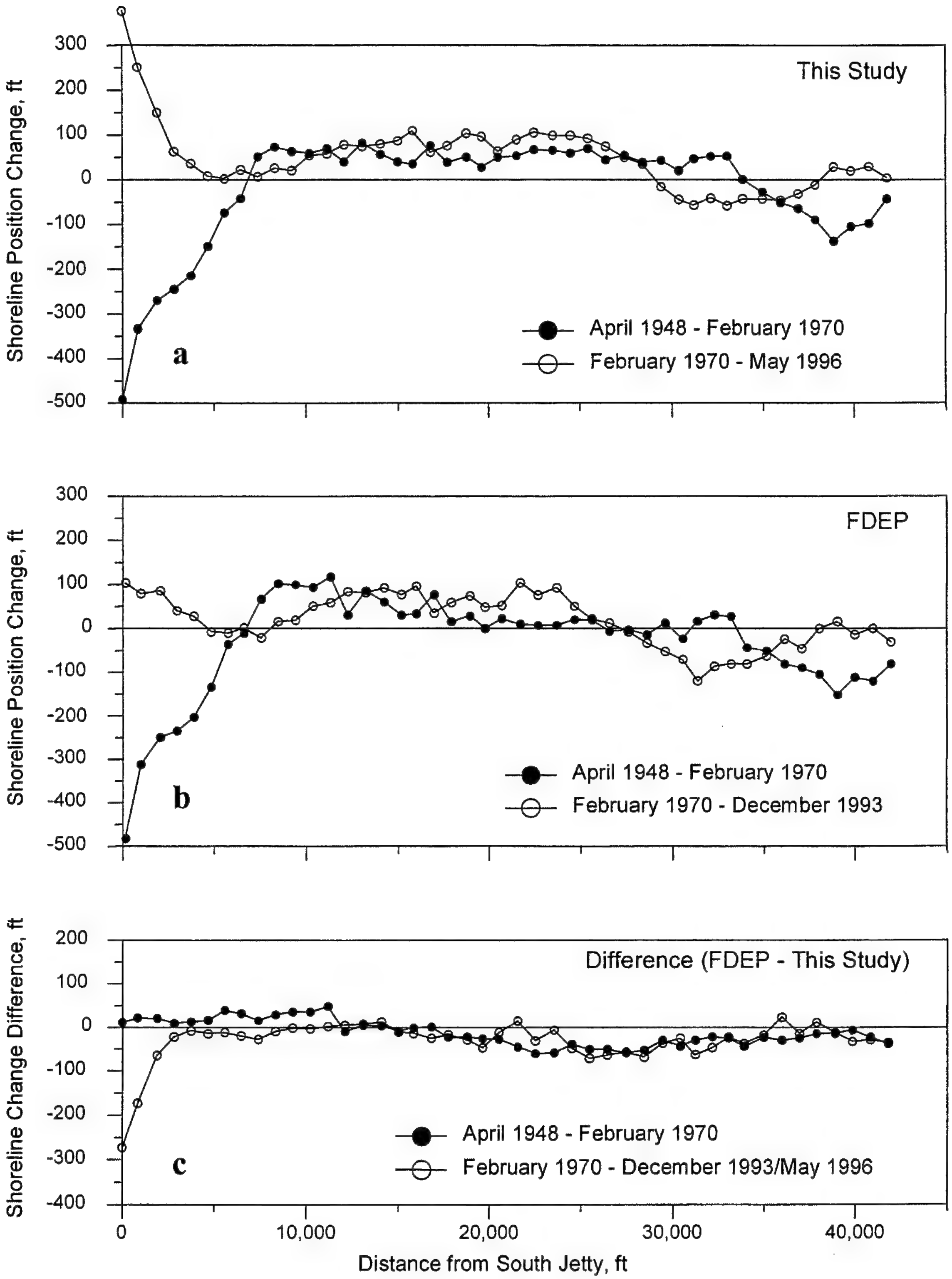

Figure 3-3. Shoreline-position change after Harbor construction from data sets analyzed (a) for this study and (b) from the FDEP.

Between April 1948 and February 1970, the shoreline receded from the south jetty to approximately 7,000 ft south. The FDEP and present study results for this period are consistent in trend and direction of shoreline change. The magnitude of advance south of 7,000 ft is less for the FDEP data than determined in the present study. Overall, shoreline adjustments between the February 1970 and December 1993 (FDEP) and from February 1970 and May 1996 (this study) show the shoreline advanced to at least 27,000 ft south of the Harbor, demonstrating the long-term effectiveness of the beach fill. Shoreline change analysis for this study shows greater advance, possibly caused by seasonal differences in the survey end dates (December 1993 for the FDEP analysis and May 1996 for this study). Greater shoreline advance adjacent to the south jetty (as shown in Figure 3-3c for the data taken in the present study) results from beach fills that occurred between December 1993 and May 1996 (Table 2-1).

FDEP beach-profile data were also analyzed to document shoreline response between September 1972 and February 1998 (see Appendix F for description of the available USACE and FDEP survey data). Because historical shoreline-position data are collected differently than beach-profile data, the different data sets were compared to determine possible inconsistencies.[18] Figure 3-4 shows potential differences that can exist between shoreline position and beach-profile survey. The April 1948 and February 1970 shorelines are from NOS surveys, whereas September 1972 was the first FDEP beach-profile survey. The trend of erosion and accretion to approximately 27,000 ft from the south Harbor jetty is consistent between the two data sets. South of this position to about 34,000 ft, the beach-profile data show recession, whereas the NOS map data show advance. The difference in trends may be due in part to the different season and date of termination (February 1970 versus September 1972). This comparison indicates that data of the same type are desirable for increasing the confidence of calculations of shoreline change.

To maintain consistency in comparing shoreline change between shoreline-position surveys and beach-profile surveys, an elevation for the HWL was estimated from beach response identified in profile surveys of beaches in the study area. Through the examination of morphologic features on beach profiles, an elevation of 8.0 ft NGVD was judged to represent the location of the HWL (this elevation is consistent with the design berm crest for past and planned USACE beach fills (USACE 1996)). For quantifying shoreline change from beach-profile surveys, the 8-ft elevation served as a surrogate for the HWL.

From September 1972 to August 1985, sand placement on the beach south of the Harbor in 1974/75 advanced the shoreline an average of 95 ft within about 26,000 ft of the south jetty (Figure 3-5). Between August 1985 and February 1998, the shoreline receded an average of 69 ft within 17,000 ft (FDEP Monument R-19) of the south jetty, while the shoreline south of this

[18] See Section 2.4: Shoreline-position surveys are continuous longshore measurements of the interpreted HWL; beach-profile surveys are measurements of elevation across the shore on lines from which shoreline position can be referenced to MHW.

erosion zone to R-48 (45,000 ft from jetty) advanced an average of 32 ft. For the period September 1972 to February 1998, the shoreline advanced an average of 42 ft for most of the coast south of the south jetty except for a 5,000-ft-long segment located between R-4 and R-9 that experienced an average 9 ft of recession (Figure 3-5). These trends indicate that, since 1972, nearly all coastal impacts (beach erosion and shoreline recession) caused by the Harbor have been mitigated by placement of sand just south of the entrance channel.

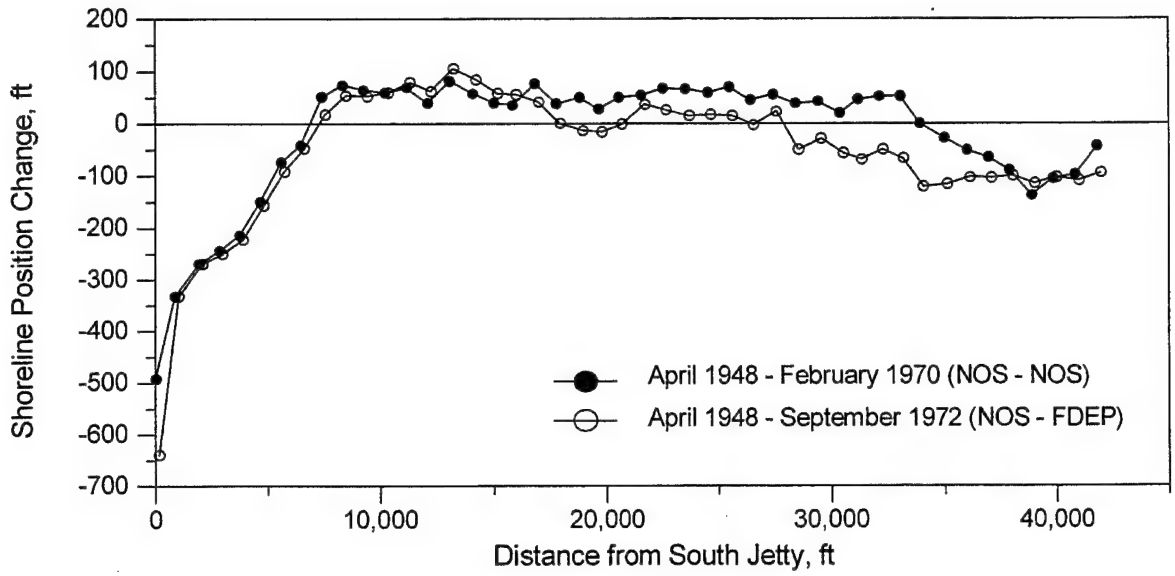

Figure 3-4. Shoreline-position change prior to the 1974/75 beach fill comparing beach response derived from NOS data to that derived from the 1948 NOS shoreline and the 1972 FDEP beach-profile data.

Shoreline-position change plotted in Figure 3-5 shows that the maximum distance of downdrift impact of Harbor construction after the 1974/75 beach fill is about 17,000 ft. Historical shoreline-position change prior to this beach fill (Figure 3-3) exhibited an impact zone located about 7,000 ft south of the Harbor. The difference in impact distances is interpreted to be associated with beach adjustments (equilibration and spreading losses)[19] after fill placement,[20] unrelated to response of the natural or native beach. After placement of sand on the beach in 1974/75, the beach south of the area of erosion located adjacent to the south jetty benefited substantially from southward sand transport.

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[19] Initially, sand placed on the beach will not be in equilibrium and will have a different slope and shoreline orientation as compared with the natural (pre-fill beach). Over several months to years, the placed material will be transported at rates greater than the naturally occurring rates. These processes are referred to as equilibration (across shore) of the profile and spreading (alongshore). Both equilibration and spreading appear as volume losses at the original site of the placement.

[20] Placement of sand on the beach in 1974/75 was the least-cost disposal alternative of sand dredged from the Harbor channel. As such, the operation was not a beach-fill project, which would have its own Federal authorization and shore protection as a main objective. However, for simplicity of language, the 1974/75 sand placement will be called a beach fill.

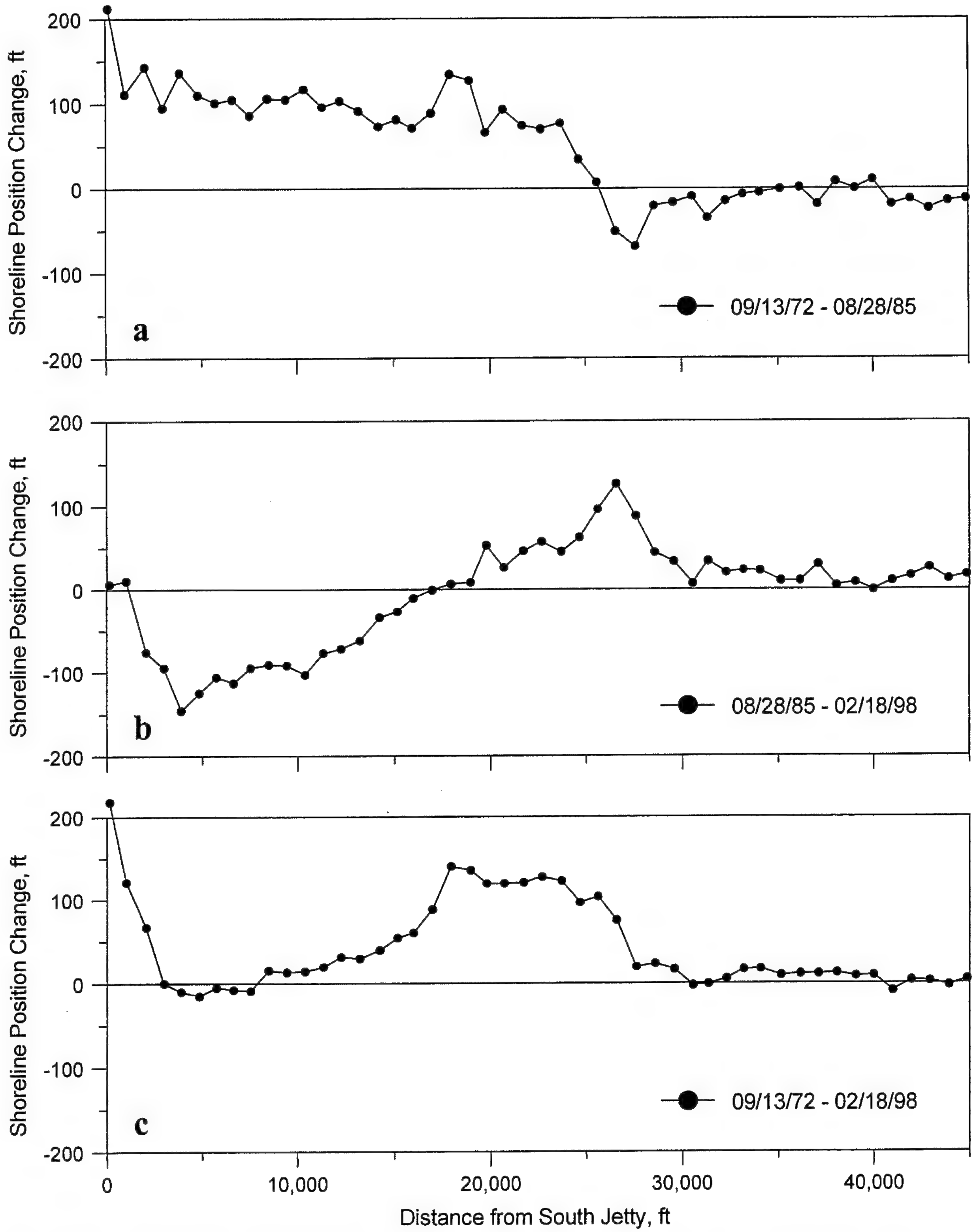

Figure 3-5. Change in high-water shoreline position south of the Canaveral Harbor entrance channel. Shoreline position change (relative to the 8-ft NGVD reference datum) was extracted from beach-profile data collected by the FDEP and the USACE.

3.3.3. *Coastal Sand-Volume Change*

Previous studies have estimated sand-volume change in the littoral zone through analysis of shoreline and beach-profile change. The present study quantified regional changes in sand volume by analysis of historical bathymetric data for the years 1929, 1956, and 1996, coupled with shoreline-position data for 1928, 1948, and 1996. The NOS hydrographic survey of 1956 is the closest survey data set available to distinguish bathymetric change before and after Harbor construction (construction of the Harbor entrance was completed 1954, see Table 2-1).

Bathymetric surfaces were generated for each time period to calculate net volume changes by comparing surfaces (see Byrnes and Hiland 1995 for methods). Pre-construction (1929-1956) and post-construction (1956-1996) bathymetric surveys were compared to quantify differences in sand-volume change and to identify sediment transport patterns in the vicinity of Canaveral Harbor. Data from the post-construction time interval provided detailed information on sand-volume adjustments in the littoral zone to assess net longshore transport rates and sand-bypassing requirements (from north to south at the entrance channel). Volume change for the interval 1929 to 1956 served as a baseline estimate of pre-construction sediment transport patterns within the vicinity of the Harbor.

Initial evaluation of volume changes from the HWL seaward to the 17-ft depth contour (NGVD) south of the Harbor was complicated by beach-nourishment activities that occurred between 1956 and 1996, introducing some uncertainty in formulating a sediment budget and associated transport rates. A central issue of this analysis was to quantify the amount of southward sand transport to estimate beach change before the Harbor was constructed. For this purpose, it was determined that analysis of volume changes north of the entrance channel jetty, combined with estimates of sand volumes dredged from the north side of the entrance channel, would provide a direct estimate of net longshore transport rates and sand-bypassing requirements.

Two assumptions were made in this analysis: (1) the Harbor is a total littoral barrier, and (2) the rate of beach-volume adjustment prior to Harbor construction is representative of changes that would have continued to beaches north of the Harbor if the Harbor had not been built. Both assumptions[21] are supported by long-term trends in shoreline- and bathymetric-change data sets (1875/78 to 1929 and 1929 to 1956). Comparison of bathymetric surfaces for the period 1956 to 1996 reveals a well-defined area of accretion north of the entrance channel jetty that extends about 12,000 ft to the north and offshore from the high-water shoreline to the 17-ft depth contour. Total sand accumulation for this zone is 8.36 ±1.46 Mcy (the potential vertical measurement error for the surface model comparison is ±1.6 ft), which includes naturally

[21] Analysis of historical shoreline and bathymetry data sets, as well as USACE dredging records for Port Canaveral, show that the Harbor has trapped all sand transported from the north that would otherwise have reached beaches south of the south Harbor entrance jetty. If the Harbor were not present, it is believed that beaches in the vicinity of the Harbor would be changing similar to that found for historical trends.

occurring additions of volume to the beach and those associated with impoundment at the jetty. Changes in sand volume for this same area from 1929 to 1956 show net accretion of 4.12 ±1.46 Mcy (natural beach volume additions). Dredging records indicate that sand deposition in two well-defined areas along the north side of the entrance channel occurs at a rate of 67,000 to 99,000 cy/year (Bodge 1994). This range of deposition rates represents the quantity of sand transported through and around the north jetty.

Given these data, the net longshore transport rate in the vicinity of the Harbor is determined as the sum of sand accumulation north of the north jetty (8.36 Mcy over 40 years gives 209,000 cy/year) and the rate of sand deposited along the edge of the north channel (maximum deposition in two areas along the edge of the north channel is 99,000 cy/year). Consequently, southerly directed, net long-term sand transport north of the Harbor (equal to net long-term sand accumulation at the total littoral barrier) has been occurring at a rate of approximately 308,000 ±28,000 cy/year. The amount of sand that was transported to beaches south of this point prior to Harbor construction is obtained by subtracting the net accretion rate in this area from 1929 to 1956 (4.12 Mcy/year over 27 years, or 153,000 ±41,000 cy/year) from the total sand accumulation rate of 308,000 cy/year. The resultant sand-bypassing rate is 155,000 ±26,000 cy/year.[22] This rate of sand bypassing is equivalent to 6.4 ±1.1 Mcy of sand for the past 41 years (1956 to 1997).

Approximately 6.3 Mcy of sand have been placed on or along the shore south of Canaveral Harbor in Brevard County, of which 4.0 Mcy were placed by the USACE and local sponsors within a 17,000-ft-long zone directly south of the Harbor, where evidence of Harbor-induced erosion exists. The remaining 2.3 Mcy of sand were placed on beaches or in nearshore disposal areas located farther than 17,000 ft south of the Harbor. Consequently, from 1956 to 1997, the supplied volume of 6.3 Mcy replaced the sand that would have been transported south by the longshore current, if not for the Harbor.

Furthermore, approximately 90% of the plaintiffs purchased their properties after 1972.[23] If 155,000 cy/year had been bypassed between 1972 and 1997, 3.9 Mcy would have been placed, which is equivalent to the amount of material (4.0 Mcy) placed by the USACE within the first 17,000 ft south of the Harbor. Calculation of shoreline-position change from measurements

[22] The USACE would not have bypassed 155,000 cy each year since 1972. If the USACE had started to bypass sand in 1972, it would have been based on the data in the 1962 authorization, and the rate of 350,000 cy/year was the stated goal at that time. The USACE did not change (lower) its estimate of bypassing until the 1987 General Design Memorandum for the Sand Transfer Plant. In 1987, the USACE estimated the net deficit for the first 2.1 miles south of the Harbor to be 136,000 cy/year, after tightening of the south jetty. The current USACE sand-bypassing rate is based on the 1993 General Re-evaluation Report rate of 106,000 cy/year. Although the 1996 USACE Feasibility Report (Appendix A, Paragraph A-96) for the Brevard County Shore Protection Project recommended a bypassing rate increase to 156,000 cy/year, this rate has not yet been implemented by the USACE. The amount of material for each future sand bypassing will be based on monitoring surveys of the borrow and disposal areas for the sand bypassing.

[23] Of these 90%, 50% purchased in the 1980s and 28% purchased in the 1990s.

shows net advance during this time period, supporting the independent estimate of sand bypassing presented above (Figure 3-3).

In summary, regional shoreline-change analysis shows that erosion of the natural (pre-project) beach that can be attributed to sand blockage by Canaveral Harbor occurs in a zone that extends about 7,000 ft south of the south jetty (Figure 3-3). Also, FDEP beach-profile data indicate net shoreline recession extending as far as 17,000 ft south of the Harbor after the 1974/75 beach fill was completed (Figure 3-5b). It is emphasized that the 7,000-ft erosion zone pertains to the natural beach (beach prior to beach fill), and the 17,000-ft erosion zone pertains to the beach-fill area. In other words, along the beach extending south from 7,000 to 17,000 ft from the south jetty, primarily beach fill has eroded and spread since its placement in 1974/75, and not the preexisting beach (prior to the fill) that was in the area. According to the present study, the bypassing rate required for mitigating Harbor-induced downdrift erosion along the beach from the south jetty to 7,000 ft south is 155,000 ±26,000 cy/year.

3.4. Impact of Storms on Brevard County Beaches

Brevard County is susceptible to erosion by tropical cyclones (hurricanes and tropical storms) and extratropical storms (northeasters). The more severe storms that have impacted the project coast are discussed in Chapter 2, and Appendix C gives an annotated listing of storms that have been documented to cause notable erosion in recent times. Erosion of the beach and dune by storms is independent of the presence of the Harbor. Therefore, at the properties of the test plaintiffs, erosion caused by storms must be estimated so that it is not attributed to the Harbor.[24]

As seen in Figure 2-6, the number of documented erosional hurricanes and tropical storms increased in the period 1947 to 1975, as compared with the periods 1899 to 1946 and 1976 to 1995. In particular, the frequency of storms became higher immediately after construction of Canaveral Harbor, for the period 1954 to 1975 (see, also, Bodge and Savage 1992).

The elevated water level (tide plus storm surge) accompanying more severe storms allows waves to reach the dune face, causing erosion. A beach berm protects the dune from wave attack and erosion by milder storms, but elevated water levels of more severe storms allow waves to travel over even a wide beach to reach the dunes. Appendix D contains photographs of dune scarping (a scarp is a vertical or near-vertical cut in the beach or dune produced by waves and currents) both to the north and to the south of the Harbor.

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[24] In contrast to storm-induced beach and dune erosion, which is rapid, accretion or buildup of beaches and dunes is a gradual process of transport of sand from the dry beach berm to the dune during times of stronger onshore wind. Dune buildup takes many years, assuming that the dunes are not disturbed and the process is left uninhibited. Along the coast south of the Canaveral Harbor, construction on top of the dunes (lawns, houses, parking lots, and shore-protection structures) interferes with the dune-building process. The dunes cannot grow in elevation with subsequent increase in width that would increase their volume. Placement of sand fences on the upper portion of the beach adjacent to the south jetty of Canaveral Harbor is a notable exception in which growth of sand dunes is promoted. A sufficient width of dry beach is required, typically about 30 ft, for full development of wind-blown sand to occur.

In summary, storm-induced erosion on the coast south of Canaveral Harbor is a predominantly unidirectional process of beach and dune-face recession and sand volume loss, independent of the Harbor. Beach erosion exposes dunes to erosion by milder storms and, if the beach narrows greatly, it reduces dune buildup by wind-blown sand. The main cause of dune erosion is the combined elevated water levels and higher, longer period waves accompanying storms.

The following sections describe calculations performed to estimate erosion of beaches and dunes produced by three severe storms documented to have severely impacted the Brevard County coast (see Table 2-1 and Appendix C). Potential beach and dune erosion is estimated by application of a numerical simulation model.[25,26]

3.4.1. Model Calibration

The SBEACH model had been previously calibrated and verified in the Feasibility Report (USACE 1996) for profile lines R-124 and R-31, respectively. Pre-storm and post-storm profile-survey data were available for Tropical Storm (TS) Gordon, which struck the Brevard County coast in November 1994 (Table 3-4). The available data are discussed in the Feasibility Report. Because periodic upgrades to SBEACH may produce slightly different final profile shapes for the same input conditions, the calibration run for Profile R-124 was repeated with the newer version of SBEACH (version 2.0) available for the present study. Also, the present study employed time series of hourly water-level measurements made at a USACE-NOS tide gauge located at St. Augustine (approximately 110 miles north of Canaveral Harbor), whereas the Feasibility Report made use of an estimated water-level time series. The estimated hydrograph was based on the measured peak surge elevation, surge duration, and tidal-cycle characteristics of Brevard County.

Confirmation of model operation for TS Gordon is shown in Figure 3-6, with the difference between calculated profiles in the present work and the Feasibility Report. The central area of interest is removal of sand and recession of the dune in the region between about 100 and 200 ft

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[25] The terminology "potential" in the present situation refers to a beach and dune that are not armored on the dune face or at the top of the dune. Armoring would reduce the actual erosion to less than the potential. The numerical model applied is called SBEACH, an acronym for Storm-induced BEAch CHange (Larson and Kraus 1989; Larson, Kraus, and Byrnes 1990). SBEACH is applied by the USACE, as well as by State agencies and private consulting companies, to estimate storm-induced dune erosion for shore-protection design.

[26] SBEACH has recently been demonstrated to perform well through comparisons of calculations against a comprehensive database of measurements in the field and laboratory (Wise, Smith, and Larson 1996). Details about the model can be found in the related references and in a number of other publications. The model calculates storm-induced dune and beach erosion produced by elevated water levels and energetic waves. Basic inputs to the model are time series (over the duration of the storm) of water level; wave height and period; initial beach profile shape; representative grain size for the beach; and various coefficients controlling calibration of the model. The principal calibration parameter is called *K*, and it and other input parameters were set to values determined in the Feasibility Report (USACE 1996). The value of *K* determined is also the default or typical value recommended for situations where calibration data are lacking, indicating the calculations were not biased.

offshore, at elevations above approximately 4 ft NGVD. The difference between the two calculations is small, with the maximum departure being at one grid cell on the dune face.

Experience with the SBEACH model, including a recent validation with a large data set (Wise, Smith, and Larson 1996), indicates that calibrated model calculations have a typical accuracy of about ±15% in estimating erosion volume above mean water level (in the present study, storm-induced erosion landward of the MHW line was tabulated). To account for uncertainties in the input data and lack of knowledge of the exact profile shape on specific dates for which information is needed in this study, a total uncertainty to the erosion-model calculations of ±25% of the calculated (best-estimate) value was assigned.

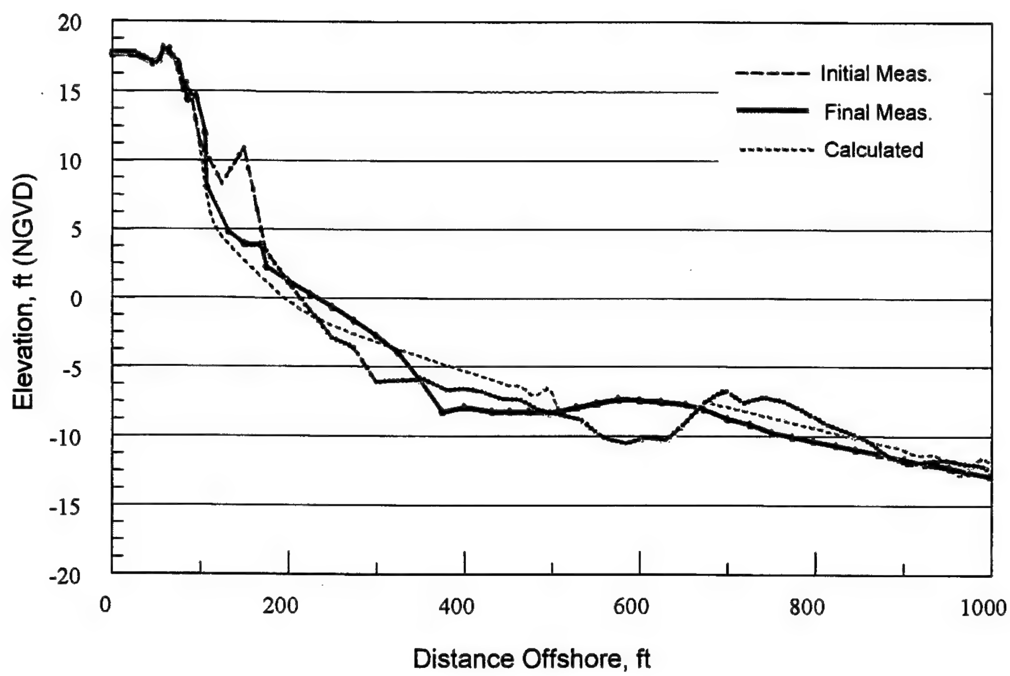


Figure 3-6. Reproduction of calibration calculation at R-124 for Tropical Storm Gordon in the Feasibility Report (USACE 1996).

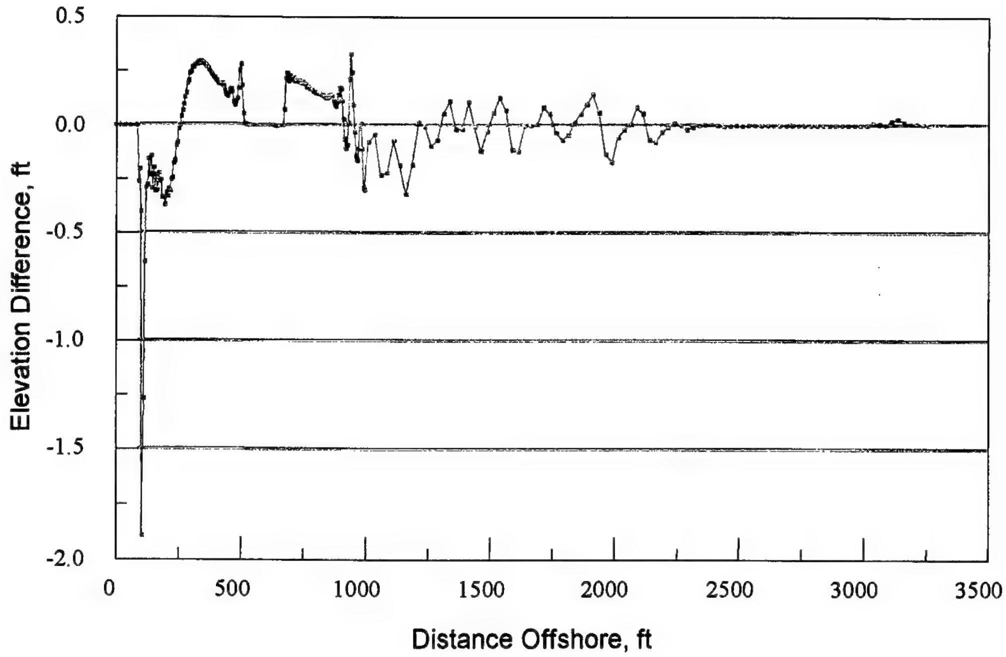


Figure 3-7. Difference in calculations between present work and Feasibility Study at R-124 for Tropical Storm Gordon (USACE 1996).

3.4.2. Three Selected Storms for Analysis

Three of the most damaging storms that occurred during or around the time of ownership were selected to investigate potential for beach and dune erosion on profile-survey lines representative of the beach and dune at the properties of the two test plaintiffs. The storms span an approximate 10-year period from late 1984 to late 1994 at approximate 5-year intervals. This period corresponds to the beach and dune condition near the times of purchase of the two test plaintiffs through to the near present. Each of these three storms was documented as having produced major damage along the Brevard County coast, and they are representative of both major types of storms, i.e., tropical and extratropical storms.

The selected storms are listed in Table 3-4, and information about their erosive damage is contained in Appendix C. Pairs of plots for each of the storms, one showing the time series of water level, and the other showing the time period of the wave height and period, are contained in Appendix E.

Table 3-4. Storms selected for beach- and dune-erosion calculations and source of water-level data.		
Storm	**Date**	**NOS Tide Gauge**
Thanksgiving Day northeaster	November 24, 1984	Mayport
(No name) Northeaster	March 11, 1989	Fernandina
Tropical Storm Gordon	November 16, 1994	St. Augustine

Thanksgiving Day northeaster 1984. This northeaster was the most devastating erosive storm to impact Brevard County in modern times. Water level (Figure E-1) was elevated through several high tides during a broad peak of high waves (Figure E-2) lasting about 3 days. Therefore, severe northeasters, which are slow moving and of large size, can be as or more erosive than hurricanes (Larson and Kraus 1991), which are typically of smaller size and faster moving.

Northeaster of 1989. A March 1989 northeaster substantially eroded the Brevard County coast, having high waves for more than 4 days through several high tides combined with storm surge. See Figures E-3 and E-4.

Tropical Storm Gordon 1994. This storm crossed the Florida Peninsula at Naples, exited at Canaveral, went along the coast to North Carolina, then returned. Elevated water level (Figure E-5) and high waves (Figure E-6) persisted over a relatively long duration (approximately 6 days) for a tropical cyclone.

3.4.3. Analysis of Storm-Induced Erosion at the Applegate Property

To conduct the analysis of beach and dune erosion by multiple storms at the Applegate property, the July 1983 FDEP profile survey at R-7 was selected to represent the pre-storm conditions for the 1984 Thanksgiving Day northeaster.[27] As discussed in Chapter 1, for the period of the analysis (November 1984 to November 1994), substantial rubble on the beach berm fronted the structure and upland of the Applegate property. Therefore, the upland <u>behind</u> the structure will not notably respond to storm action, because the rubble serves as shore protection or armoring, similar to, but not as efficient as, a rubble revetment or a bulkhead. The beach and dune can only erode to the rubble, which was the situation after placement of the 1974/75 fill.

[27] Horizontal coverage offshore is coarse at 50-ft intervals, but the survey extends from landward of the dune crest to an elevation of -5.89 ft NGVD. To complete the profile so that it could serve as a realistic initial condition for subjection to the three storms, the December 1993 offshore survey data for R-7 were appended from elevation –5.9 ft and translated as required. After the dune-erosion calculation for each storm was completed, the resultant calculated profile, which was in equilibrium with the storm, was replaced with data from the December 1993 survey from the +4-ft elevation to the seaward limit of the survey data. This combination of profiles provided a realistic and consistent profile shape to serve as the next initial condition for the subsequent storm.

Calculation results at R-7 for the three selected storms, with the final profile position as post-TS Gordon, are shown in Figure 3-8. The storms caused substantial erosion on the upper beach. Specifically, as listed in Table 3-5, the MHW shoreline receded approximately 15 ft during the Thanksgiving Day storm, 31 ft during the March 1989 northeaster, and 24 ft during the 1994 Tropical Storm Gordon. The SBEACH model produced some washover, which is the landward transport of sand.

Table 3-5 summarizes both the MHWL recession and maximum net loss of beach and dune volume landward of the location of the MHWL in the units of cubic yards per foot (cy/ft) of beach alongshore. Offshore sand transport rates ranged between 10.8 and 11.9 cy/ft. Using the conversion that 1 cy/ft = 2.5 cu m/m, the maximum transport rates fall in the range of 27 to 29.8 cu m/m of berm crest. These rates are in the midrange of storm-induced beach and dune-erosion rates as documented by Savage and Birkemeier (1987) measured for 13 storms at several northeastern beaches of the United States facing the Atlantic Ocean. It is noted that the calculated beach and dune erosion and recession corresponds to a profile that is not armored. Such would have been the case for the fill placed along the beach in 1974/75. The cumulative eroded volume from the storms is calculated as (11.9+11.3+10.8 cy/ft) x 106 ft = 3,600 cy.

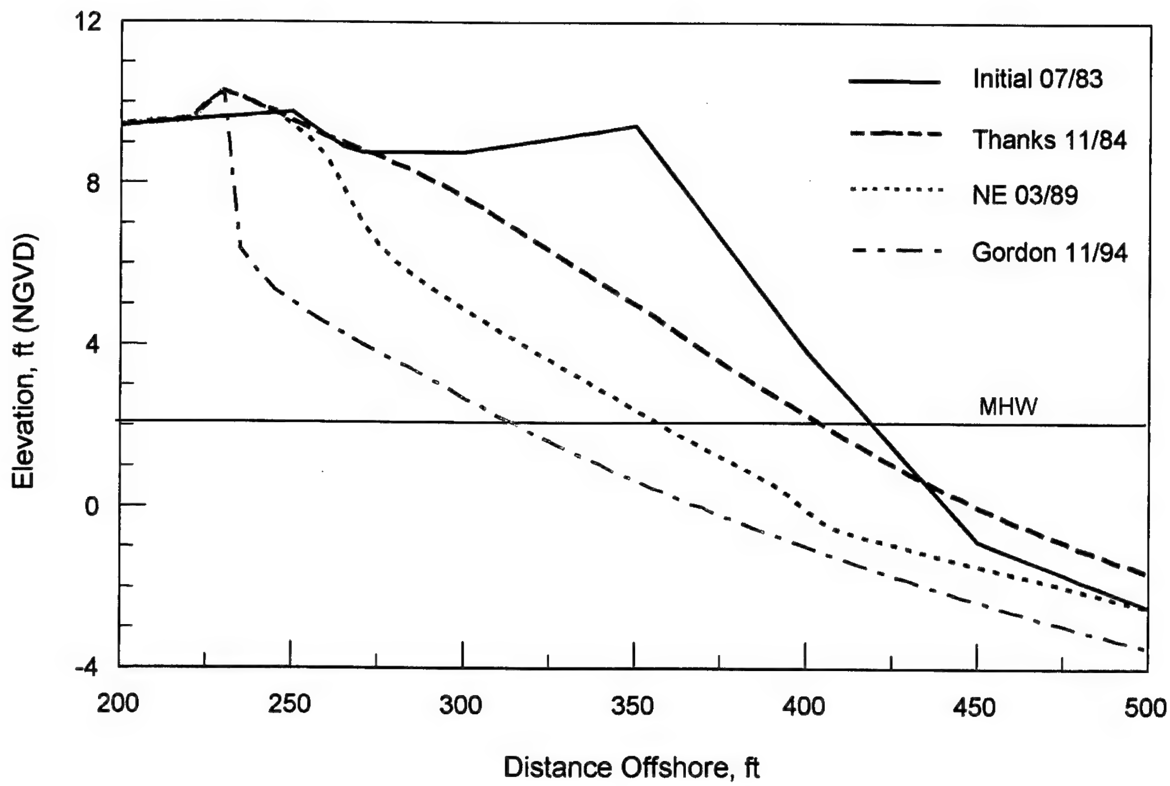


Figure 3-8. R-7: Beach recession by three selected recent storms.

Table 3-5. Summary of potential erosion of Profile Line R-7 by three selected storms.		
Storm Sequence	**Change of the MHWL, ft**	**Maximum Volume-Loss Rate, cy/ft**
Initial 07/1983 – Thanksgiving NE 11/1984	-15.0	-11.9
Post-Thanksgiving NE 11/1984 – NE 03/1989	-30.9	-11.3
Post NE 03/1989 – TS Gordon 11/1994	-23.8	-10.8
Total Change of the MHWL, 07/1983 to 11/1994 (three storms)	**-69.7**	--

For comparison, beach-profile change between September 1972 and December 30, 1993, measured at R-7 and R-8 is plotted on Figure 3-9. Numerical calculations of beach-profile change for the three storms, with survey data from R-7 as the initial condition, give recession and erosion less than that documented by the surveys as described below. The magnitude of erosion at R-8, located approximately 900 ft to the south of R-7, is less significant because the nearest survey in time occurred on August 27, 1985. Comparison of the August 1985 surveys for both R-monuments indicates similar beach dimensions relative to the position of the dune.

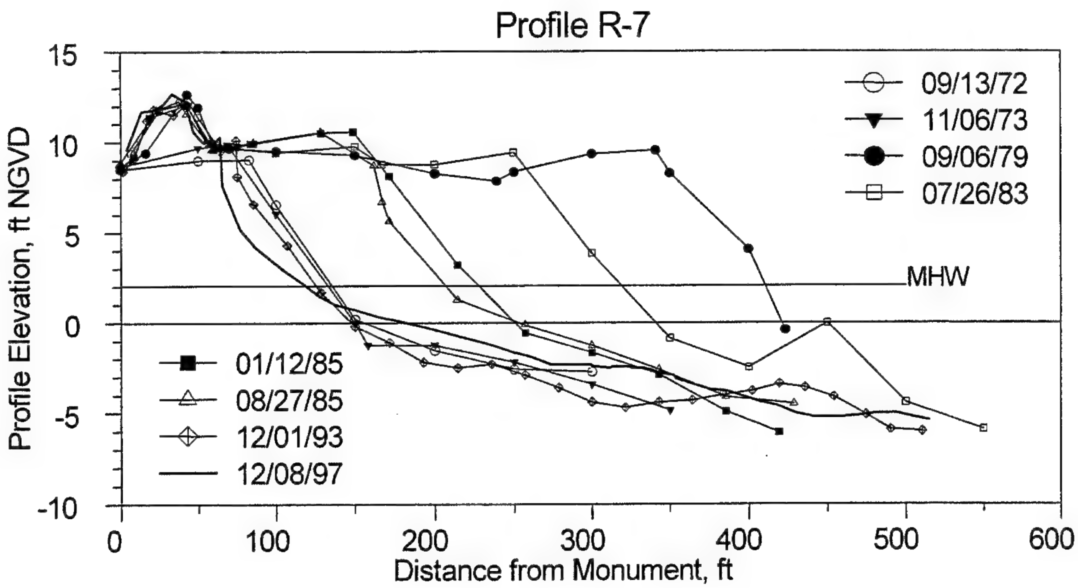
3.4.4. Analysis of Storm-Induced Erosion at the Noro Property

Profile Line R-43 was selected to represent the condition of the beach and dune near the Noro property. Remnants of a wooden bulkhead (apparently destroyed in the 1984 Thanksgiving Day northeaster), sand-filled bags, and some stone rubble presently front this property. Therefore, the dune behind these objects will be protected against mild storms, but not against severe storms.

To conduct the calculations of dune erosion by multiple storms, the FDEP profile-survey data at R-43 for May 1982 were selected to represent the beach and dune.[28] This survey was made just prior to the devastating 1984 Thanksgiving Day storm. Coverage for the survey extends from landward of the dune crest to an elevation of –6.5 ft NGVD. To complete the profile so that it could serve as a realistic initial condition for subjection to the three storms, the December 1993 survey data for R-43 were appended from elevation –7.5 to –32 ft NGVD.[29]

[28] For the calculation, the stone revetment located at the dune on Survey Line R-43 was not included (although this is possible in SBEACH) in order to calculate storm-induced erosion of a profile representative of that at the Noro property.

[29] A point at –32-ft elevation was added to the profile some 4,000 ft offshore to extend the measured profile and allow random storm waves to break beyond the limit of the actual survey data at elevation of about –25 ft. After the dune-erosion calculation for each storm was completed, the resultant calculated profile, which was in equilibrium with the storm, was replaced with data from the December 1993 survey from the +4-ft elevation to the seaward limit of the survey data. This combination of profiles provided a realistic and consistent profile shape to serve as the initial condition for the subsequent storm.



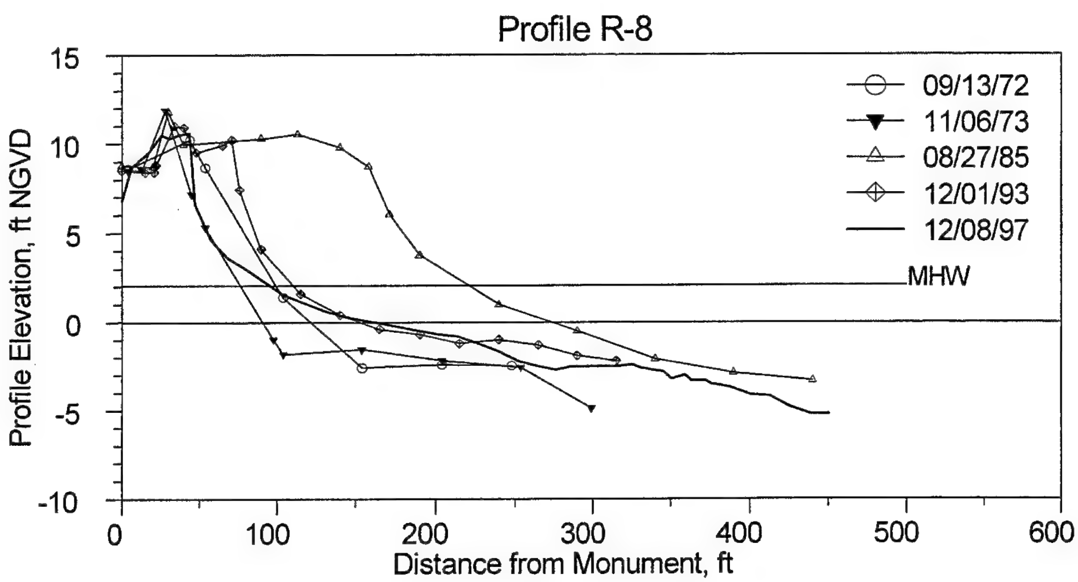


Figure 3-9. Beach profile change at FDEP Monuments R-7 and R-8.

Calculation results at R-43 for the three selected storms, with the final profile position as post-TS Gordon, are shown in Figure 3-10. The storms caused moderate beach erosion and recession of the dune face, with the Thanksgiving Day northeaster of November 1984 producing the most erosion.[30] In comparison with the beach recession calculated at R-7 for Applegate

[30] The SBEACH calculation for R-43 advanced the MHWL approximately 17 ft. Material contributing to advance the MHW shoreline was taken from the dune and upper beach.

(Figure 3-8), recession at R-43 is considerably less. The smaller recession at R-43 is attributed to the beach-face slope being closer to equilibrium than at R-7.

For R-43, SBEACH produced no washover because the dune crest was higher than the highest wave runup. Table 3-6 summarizes calculated change in MHW shoreline position and the loss of dune and beach volume landward of the location of the MHWL. Volume lost landward of the MHWL ranged between 2.1 and 3.9 cy/ft or 5.3 and 9.8 cu m/m of dune crest. These rates are in the lower range of storm-induced dune-erosion rates as documented by Savage and Birkemeier (1987).

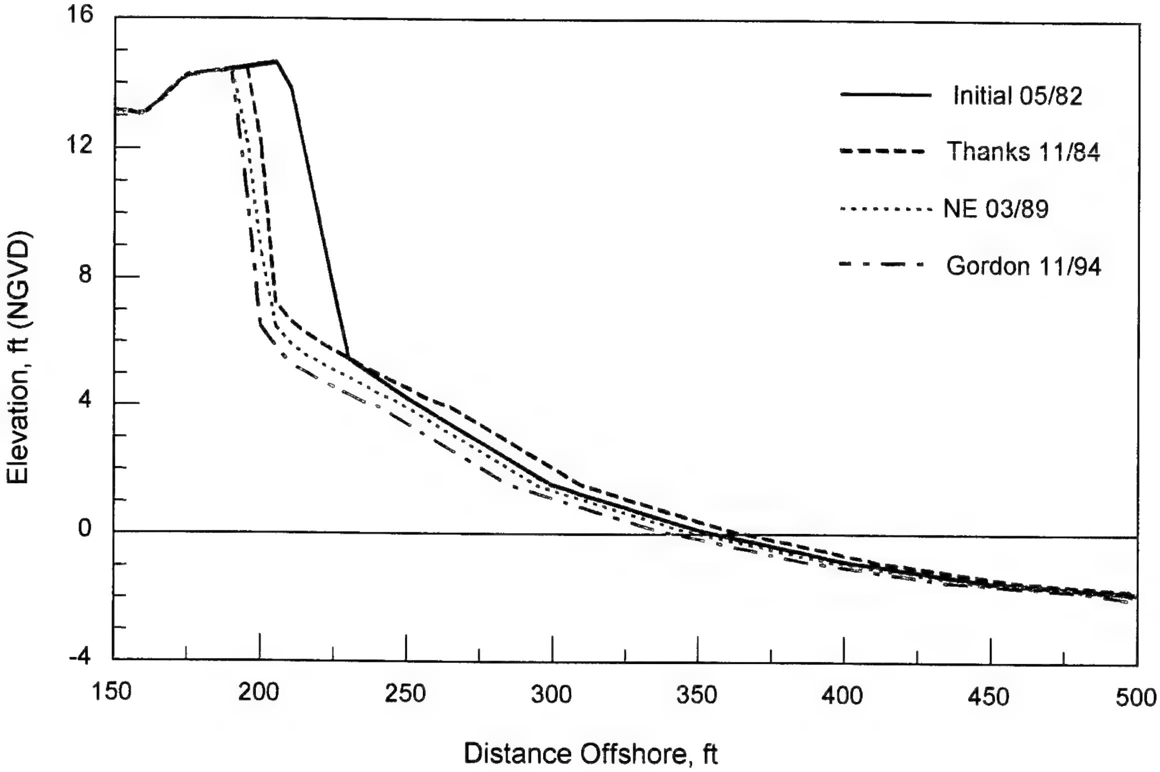


Figure 3-10. R-43: Beach recession by three selected recent storms.

Table 3-6. Summary of potential erosion of Profile Line R-43 by three selected storms.

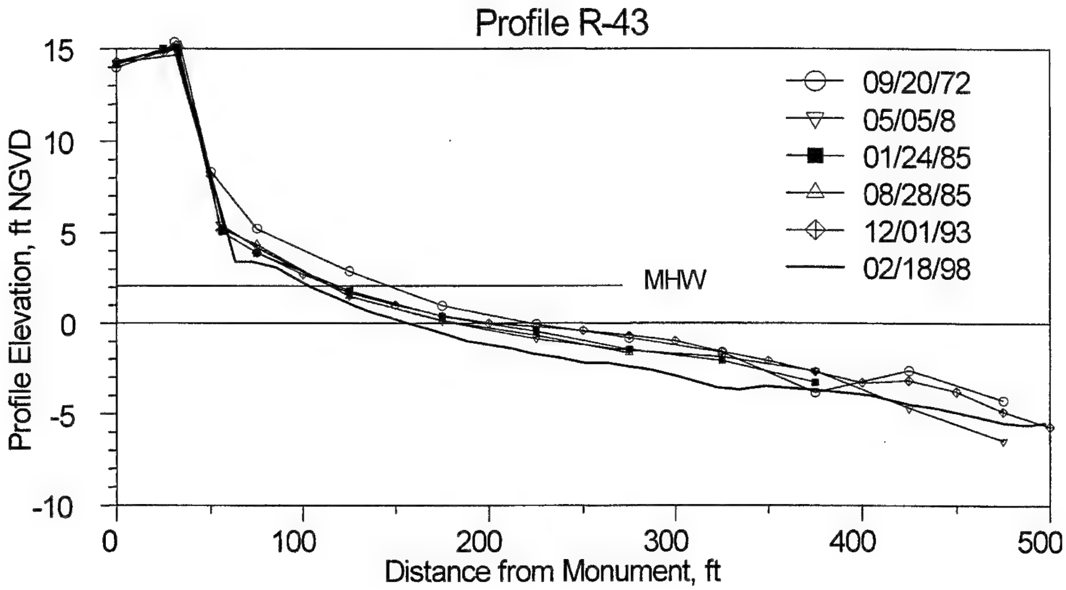
Storm Sequence	Change of the MHWL, ft	Maximum Volume-Loss Rate, cy/ft
Initial 05/1982 – Thanksgiving NE 11/1984	+17.1	-3.9
Post-Thanksgiving NE 11/1984 – NE 03/1989	-1.7	-2.8
Post-NE 03/1989 – TS Gordon 11/1994	-1.0	-2.1
Total Change of the MHWL 05/1982 to 11/1994	**+14.4***	--

* From 1986 to 1996 (bracketing time of ownership) the MHWL change was calculated to be -2.7 ft

For comparison, beach-profile change between September 1972 and February 1998 measured at R-43 and R-44 is plotted on Figure 3-11. Profiles at Monument R-43 exhibit limited change from the dune crest to the MHW shoreline between May 1982 and December 1993. The lack of change at the dune face is attributed to shore-protection armoring. Profile R-44, 1,000 ft to the south, has not been armored, and the beach and dune responded differently to the storms.

From September 1972 to January 1985, at least 19 storms impacted the Brevard County coast (Appendix C). At R-44, the upper beach and dune face receded about 30 ft (Figure 3-11), mainly in response to the 1984 Thanksgiving Day storm. Significant beach and dune recession was described in the local newspapers for the Noro property and at other properties as a consequence of this storm. Calculations of beach and dune erosion caused by storms were performed for the profile at R-43 without representing the armoring. The modeling calculations produce almost the same erosion as that measured at R-44, which is not armored.

Similar to beach changes recorded at R-7, where simulated storm impacts accounted for a significant portion of measured erosion and recession, all of the erosion on the upper beach (above 5 ft NGVD) and the dune face at R-43 and R-44 can be attributed to storm-induced erosion. Storm-induced beach-volume loss at Noro for the time of purchase is calculated from Table 3-6 as (2.8+2.1 cy/ft) x 100 ft = 490 cy.



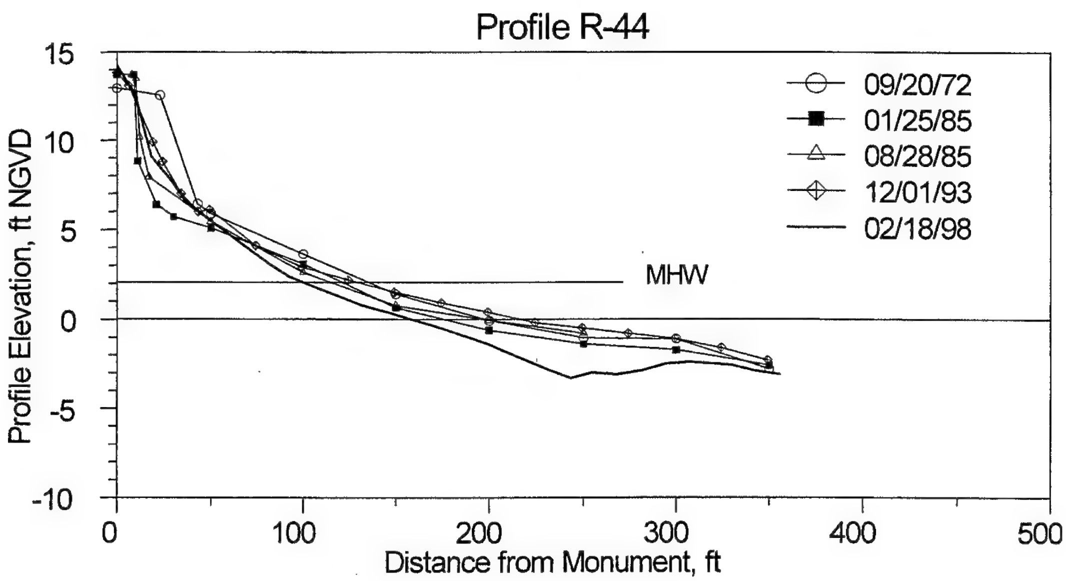


Figure 3-11. Beach profile change at FDEP Monuments R-43 and R-44.

4. Test Plaintiffs' Properties

This chapter presents an analysis of the coastal property losses and gains experienced by the test plaintiffs. The analysis draws directly from procedures and material described in the previous chapter dealing with long-term regional coastal processes and storm impacts.

4.1. Data Analyzed

Surveys of beach profiles made by the FDEP and the USACE were analyzed for calculating changes in shoreline position and beach volume at the properties of the test plaintiffs according to the Joint Protocol (Appendix B, Tier 4a). These surveys constitute the primary database for quantifying shoreline position and sand-volume change as close to test plaintiffs' properties as possible. Accuracy of the profile survey procedure is high (plus or minus inches). However, the profile lines are approximately 1,000 ft apart, and interpolation is necessary to estimate shoreline position at the properties. Variability in shoreline position associated with interpolation between profiles at Applegate is estimated at ±10 ft based on small variations in shoreline orientation between profiles in August 1981. Estimated shoreline-position variability between profiles bracketing the Noro property is ±15 ft because the upland area fronting the property in September 1986 was offset seaward of the MHWL for adjacent profiles.

4.2. Applegate Property

The first test plaintiff, Don and Gale Applegate, own a 106.16-ft-wide parcel with the northern boundary located approximately 305 ft south of Monument R-7. Until about September 1997 the structure on the property was a single-family, two-story house that was originally constructed around 1960. In February 1997, the structure was determined to be unsafe by the City of Cape Canaveral, which required its removal. Because the house was vulnerable to collapse, the City deemed the structure to be unsafe and issued a demolition permit on July 31, 1997; according to the City building inspector, the house and rubble were removed by March 8, 1998.

Don and Gale Applegate purchased their property in August 1981 for $15,000. At the time of purchase, there was no dune in front of the structure, but much of the 1974/75 beach fill still remained. Figure 4-1 shows the location of the Applegate house relative to the dune line in August 1971, and Figure 1-2 shows almost the same view in May 1996. The house had been located approximately 200 ft seaward of all other houses south of the Harbor in Brevard County. In the 1960s, concrete rubble and automobile parts were placed in front of the property in an attempt to protect against storm waves and flooding (Figure 4-1 and Figure 4-2) and were still

present in December 1997 (Figure 4-3 and Figure 4-4).[31] Because of its extreme seaward location relative to all other houses and structures along the beach in its vicinity, the Applegate structure was always vulnerable to wave action and flooding during times of annual extreme high waters that accompany storms and hurricanes. During the October 1974 tropical depression, a part of the Applegate structure crumbled into the ocean.

Prior to its removal in March 1998, the rubble in front of the Applegate property formed a barrier, similar to the Canaveral Harbor jetties, to sediment moving alongshore. Because the net direction of sediment transport is to the south, the Applegate rubble deprived beaches to the south of material. Figure 4-3 shows the beach of the adjacent property to the south (see also aerial views in Figures D-8 and D-10).

The 1974/75 beach fill resulted in placement of 2.8 Mcy of beach-quality dredged material within the first 2 miles of the south jetty. The fill buried the rubble at the Applegate property and advanced the June 1973 MHWL about 530 ft, based on the "typical" construction cross section for the area contained in FDEP construction permit No. BBS 73-74-4. After adjustment of the fill, the shoreline was located approximately 300 ft seaward of the pre-fill MHWL (see Figure 3-9) and had buried this rubble at the Applegate property.

Figure 4-1. Applegate property, August 1971. Presence of pilings and concrete rubble indicates this particular structure was vulnerable to wave action 10 years after construction (source: USACE, Jacksonville).

[31] The Applegates, including prior owners within the family, had placed such rubble on the beach periodically since the 1960s. Its presence is documented in local newspapers (*Orlando Sentinel*, 10/18/68, 10/23/68, 11/05/68, and 07/17/69; and *Florida Today* 02/25/72, 03/31/72, and 05/06/73).

Figure 4-2. Applegate property viewed from the south adjacent property, February 20, 1997. Location of Applegate residence and rubble on the beach face and in front of the dune line is clearly evident (source: N. C. Kraus).

Figure 4-3. Seaward side of the Applegate property, December 3, 1997. Main structure was removed by Mr. Applegate around September 1997; however, the foundation of the dwelling and the rubble in front of the structure still remained (source: N. C. Kraus).

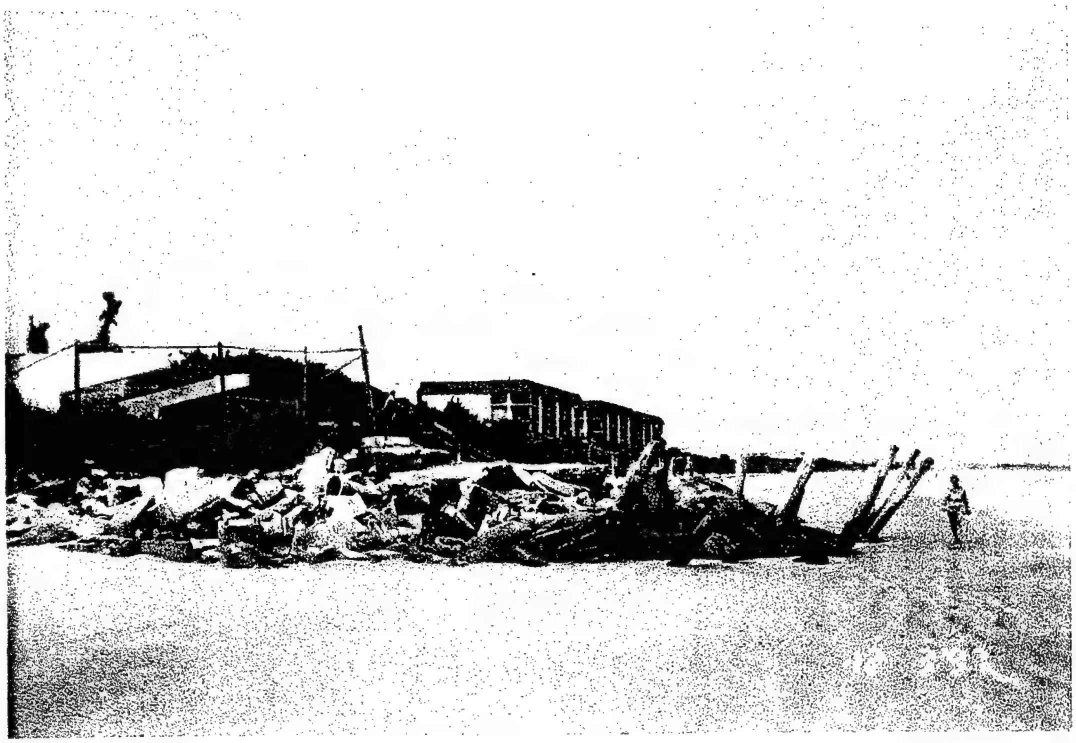


Figure 4-4. Side view of Applegate property, December 3, 1997 (source: N. C. Kraus).

In November 1984, the destructive Thanksgiving Day northeaster storm eroded the eastern shores of Florida. Some of the greatest damage by the storm took place in Brevard County (Balsillie 1985). The storm also caused major damage at the Applegate residence and unearthed the rubble that had been covered by the 1974/75 beach fill.

The Applegates commissioned a boundary survey of their property in August 1981. However, the survey does not define the MHWL or any other seaward property boundary. Plaintiffs' counsel commissioned a current-condition survey for the property in March 1996, and this survey does indicate the location of the MHWL, as well as the location of the structure and the rubble on the property at that time.

Repetitive surveys of the beach profile at FDEP Monuments R-7 and R-8 document change in shoreline position and in sand volume between August 1981 and December 1997. At Monument R-7, the surveys closest in time agreeing seasonally to the purchase date were those made on September 6, 1979, and July 26, 1983.[32] The MHWL location for these two surveys was obtained by linear interpolation in time to estimate the August 12, 1981, shoreline position. At Monument R-8, a slightly different procedure was applied to establish the MHWL at the purchase date. The two profiles bracketing the time of purchase were surveyed on November 6,

[32] A USACE beach-profile survey was performed at R-7 on December 1979, which makes it the closest in time to the purchase date, but this survey would contain the winter position of the shoreline and would not be compatible with the August purchase date and the July 1983 survey.

1973, and on August 27, 1985. Temporal linear interpolation between adjacent profiles (R-7 and R-8) was not appropriate for this situation because of the major beach fill placed in 1974/75, significantly advancing the shoreline position. Therefore, trends identified to exist between August 27, 1985, and December 1, 1993, were extrapolated to estimate shoreline position and beach-profile characteristics on August 12, 1981. These estimates established the MHWL and beach-profile shape at the Applegate property based on distance from the monuments.

4.2.1. Shoreline Change

Once an estimate of MHWL location was established for the purchase date, shoreline positions between August 12, 1981, and December 8, 1997, were compared. The difference in shoreline position for these dates is -237 ft at R-7 and -177 ft at R-8 ("minus" denoting recession). The difference in shoreline recession at R-7 and R-8 is consistent with the expected decrease in recession with distance from the jetty. Therefore, the proportionate change in shoreline position at the Applegate property has been approximately –216 ±7 ft (recession) since August 12, 1981, a recession rate of about 13 ft/year.

4.2.2. Volume Change

Applying the same interpolation procedures described above, change in beach sand volume landward of the MHWL was calculated. Change in sand volume between August 12, 1981, and December 8, 1997, at R-7 and R-8 are -89 and -65 cy/ft, respectively (See Figure 4-5 and Figure 4-6). Consequently, the volume lost landward of the August 12, 1981, MHWL to present, associated with the 216 ft of shoreline recession, is estimated as 80 cy/ft x 106 ft ≈ 8,500 cy.[33]

Calculation of erosion at R-7 as caused by three of several storms that struck the Brevard coast after time of purchase indicated that at least 3,600 cy of material were lost by storm impacts. Therefore, at least 3,600/8,500 x 100 = 42 ±21% of sand-volume loss since time of purchase is accounted for by storm-induced erosion that cannot be attributed to the Harbor.

[33] The value of 8,500 cy is an overestimate of loss because the natural beach and dune adjacent to the Applegate property (used to estimate loss at Applegate) eroded more than the armored Applegate property.

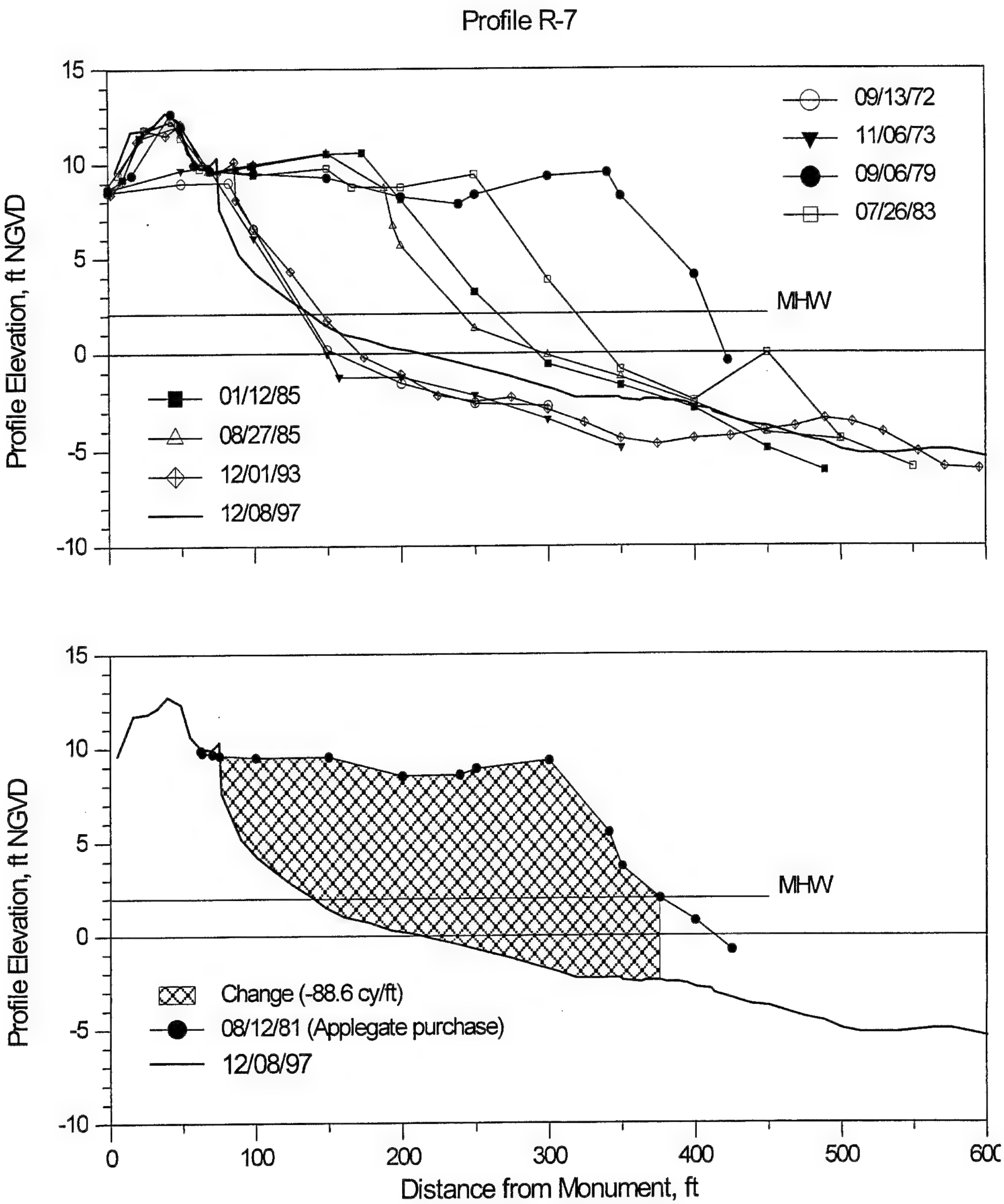
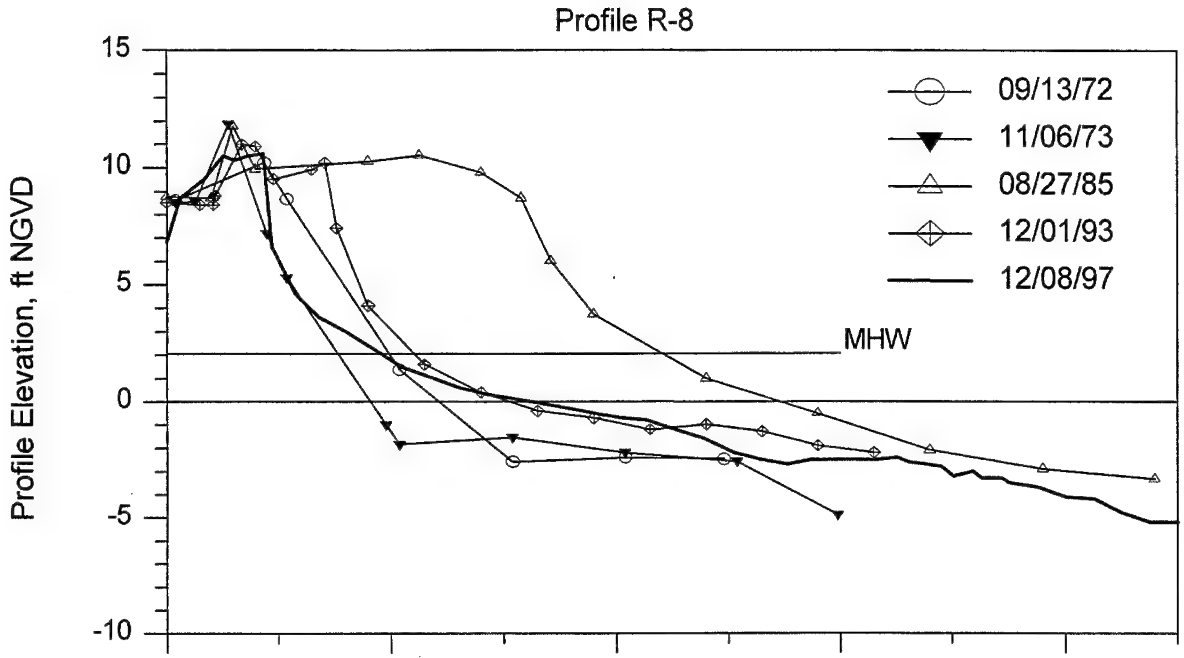


Figure 4-5. Beach profile surveys at Monument R-7 and calculated volume loss from the time of purchase (August 12, 1981).



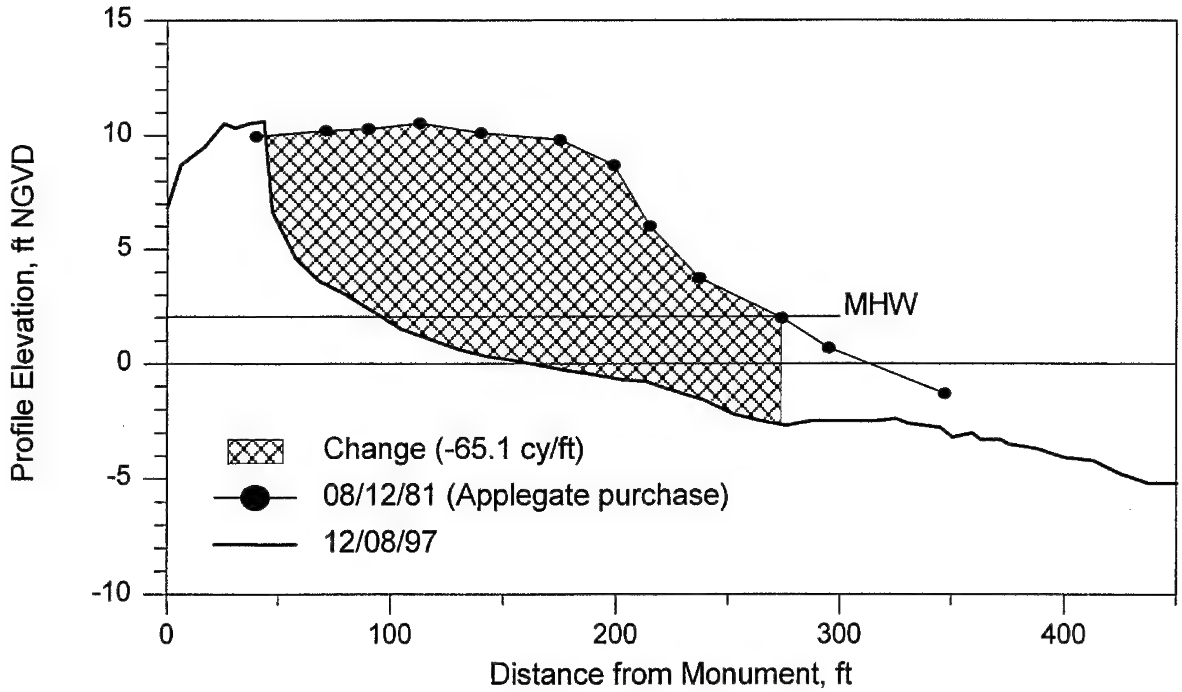


Figure 4-6. Beach profile surveys at Monument R-8 and calculated volume loss from the time of purchase (August 12, 1981).

4.3. Noro and Company Property (Pelican Landing Resort)

The second test plaintiff is Noro and Company, former owners of the Pelican Landing Resort (Figure 4-7). The Noro Company purchased the property from Pelican Landing Resort, Inc., on September 8, 1986, and 10 years later, on September 11, 1996, they sold the property to Ms. Sandra Daniels for $387,500 (a $125,500 profit). No survey is available for the purchase conditions of the property, but a survey commissioned by plaintiffs' counsel dated March 1996 does exist and represents conditions near the selling date. The March 1996 survey contains the location of the structures on the property and the property boundaries, including the MHWL.

The northern border of the property is located 395 ft south of Monument R-43, and the property is 100 ft wide. The adjacent beach properties in this area are mostly armored. Presently, the Noro property is protected by sandbags (geotextile armoring units) placed around its seaward perimeter, and remnants of a rock revetment (or rubble) and a wooden bulkhead can be observed (see Figures 4-7 and 4-8). The bulkhead protected the property prior to the time of purchase, but it was destroyed in the Thanksgiving Day northeaster of 1984.

The 1984 Thanksgiving Day northeaster struck the coast of Brevard County 2 years before Noro purchased the property. This storm removed the beach, destroyed the wooden bulkhead built to protect the property against storm waves, and eroded the dunes at the site. A local newspaper (*Florida Today* 11/24/84) reported that the foundation of "Pelican Landing Resort in Cocoa Beach hangs over dunes edge…" after the Thanksgiving Day storm. The remains of the wooden bulkhead can be seen in Figures 4-7 and 4-8. This bulkhead indicates response to and anticipation of dune erosion caused by storms, because long-term change of the MHW shoreline has been negligible for at least 30 years. During low tide, a substantial beach is observed in front of the Noro property, as seen in Figure 4-9.

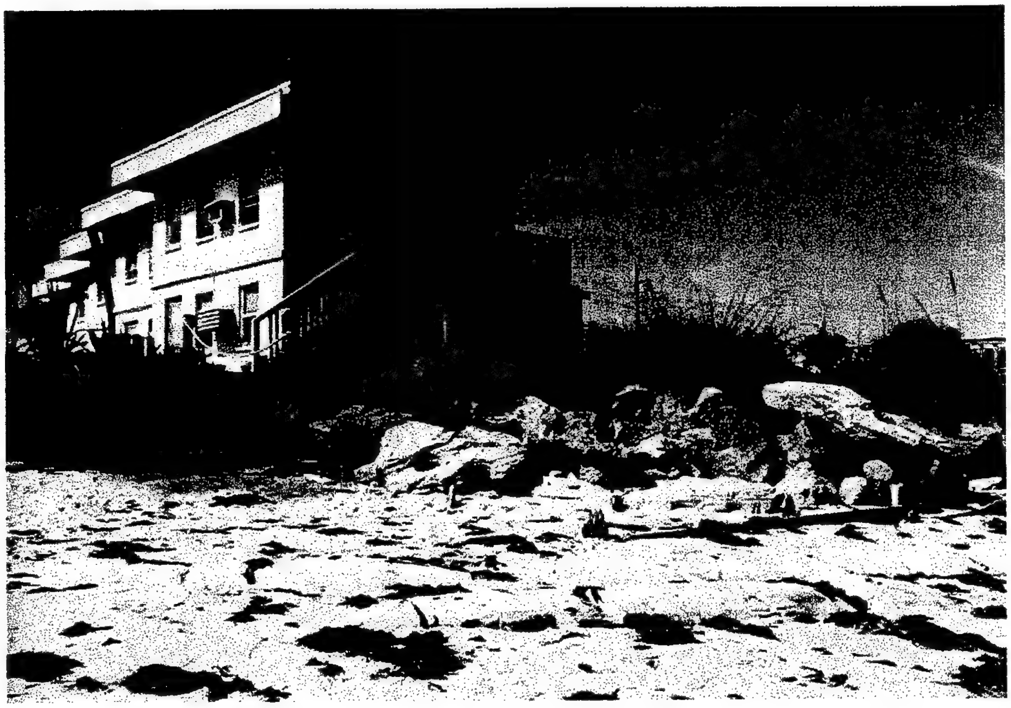


Figure 4-7. View of rock revetment and remnant wooden bulkhead seaward of the Pelican Landing Resort, February 20, 1997 (source: N. C. Kraus).

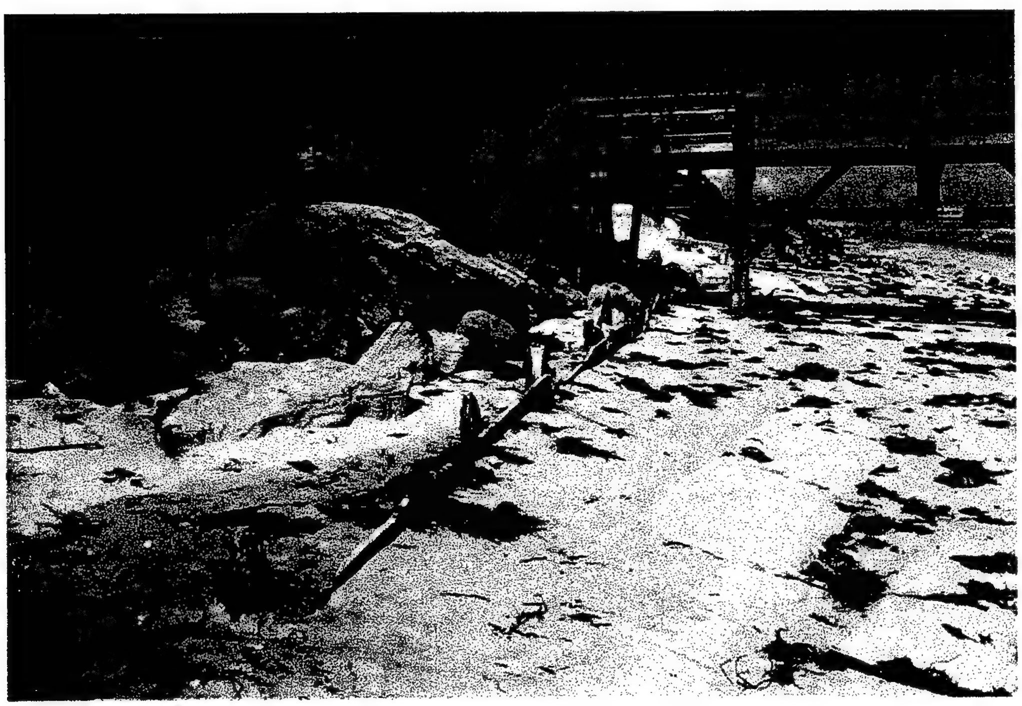


Figure 4-8. Oblique view of remnant wooden bulkhead, rock revetment, and sandbags along the seaward side of the Noro Property (Pelican Landing), February 20, 1997 (source: N. C. Kraus).

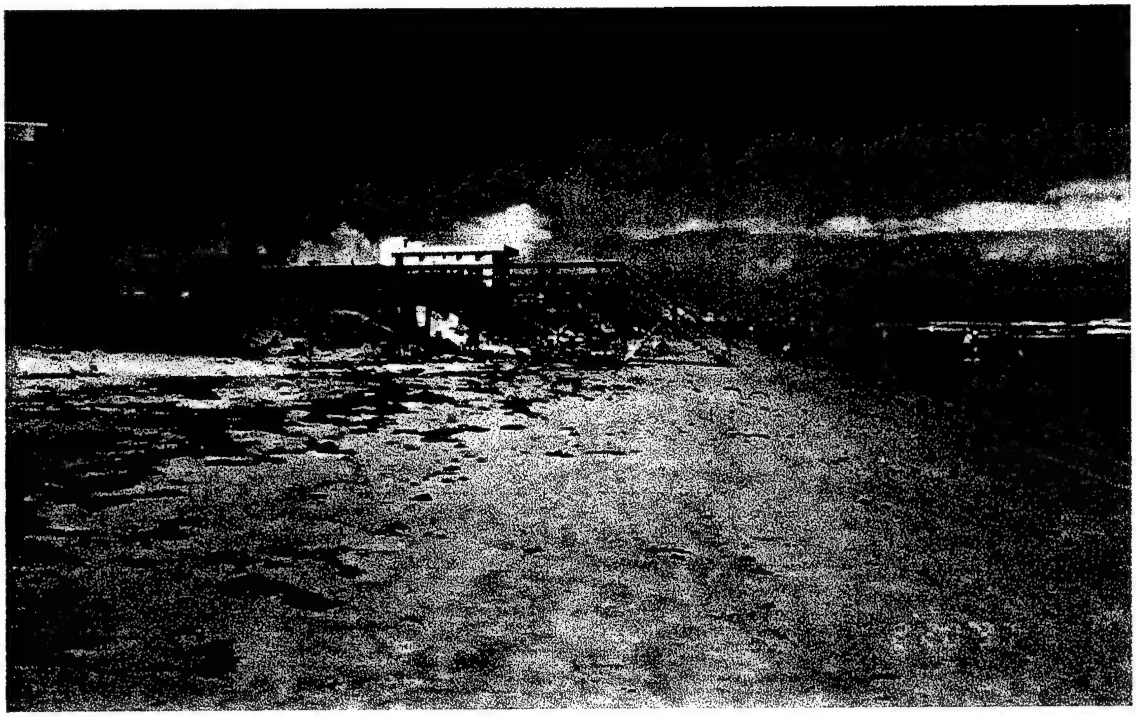


Figure 4-9. View north of Noro property with a wide beach, February 20, 1997 (source: N.C. Kraus).

4.3.1. Shoreline Change

Calculation procedures adopted to establish the magnitude of change in shoreline position and sand volume for the Applegate property were applied in quantifying change at the Noro property. The two beach-profile surveys bracketing the purchase date at Monuments R-43 and R-44 are August 28, 1985, and December 1, 1993. After establishing the MHWL (2.06 ft NGVD) associated with R-43 and R-44 (based on tidal datums for that locale), change in shoreline position was calculated at each line. At both R-43 and R-44, the MHWL on September 11, 1996, receded approximately 9 ft since the time of purchase (September 8, 1986). Therefore, the MHWL at the Noro property (which lies between the two monuments) also receded 9 ft during the time of ownership. Given previously discussed uncertainties in estimating shoreline position through interpolation between different seasons, a 9-ft change in shoreline position over a ten-year period cannot be considered a trend (does not signify a change).

4.3.2. Volume Change

Configurations of beach profiles at R-43 and R-44 were established for the period of ownership by interpolation between profiles bracketing September 8, 1986, and September 11, 1996. Changes in sand volume are 1.4 and 0.0 cy/ft net erosion at R-43 and R-44, respectively (See Figure 4-10 and Figure 4-11). These values produce an average loss in sand-volume per

linear foot of beach at the Noro property of 0.8 cy/ft, which is a total loss of 80 cy for the 100 ft of beachfront for the time of ownership.

In agreement with the loss in sand volume determined from measurements at the Noro property during the time of ownership, numerical calculations of potential[34] storm-induced beach and dune change indicate that the volume loss on the upper beach and dune south of the property (Monument R-44) was caused by storms. The existing armoring at the property should prevent dune erosion by wave action during ordinary high tides, so that only elevated water levels that accompany major storms will erode the dune face. Therefore, storms are deduced to be the dominant factor producing dune recession at the Noro property and not blockage of longshore sand transport by Canaveral Harbor.

[34] The word "potential" indicates that armoring was not taken into account in the calculations of storm-induced beach erosion.

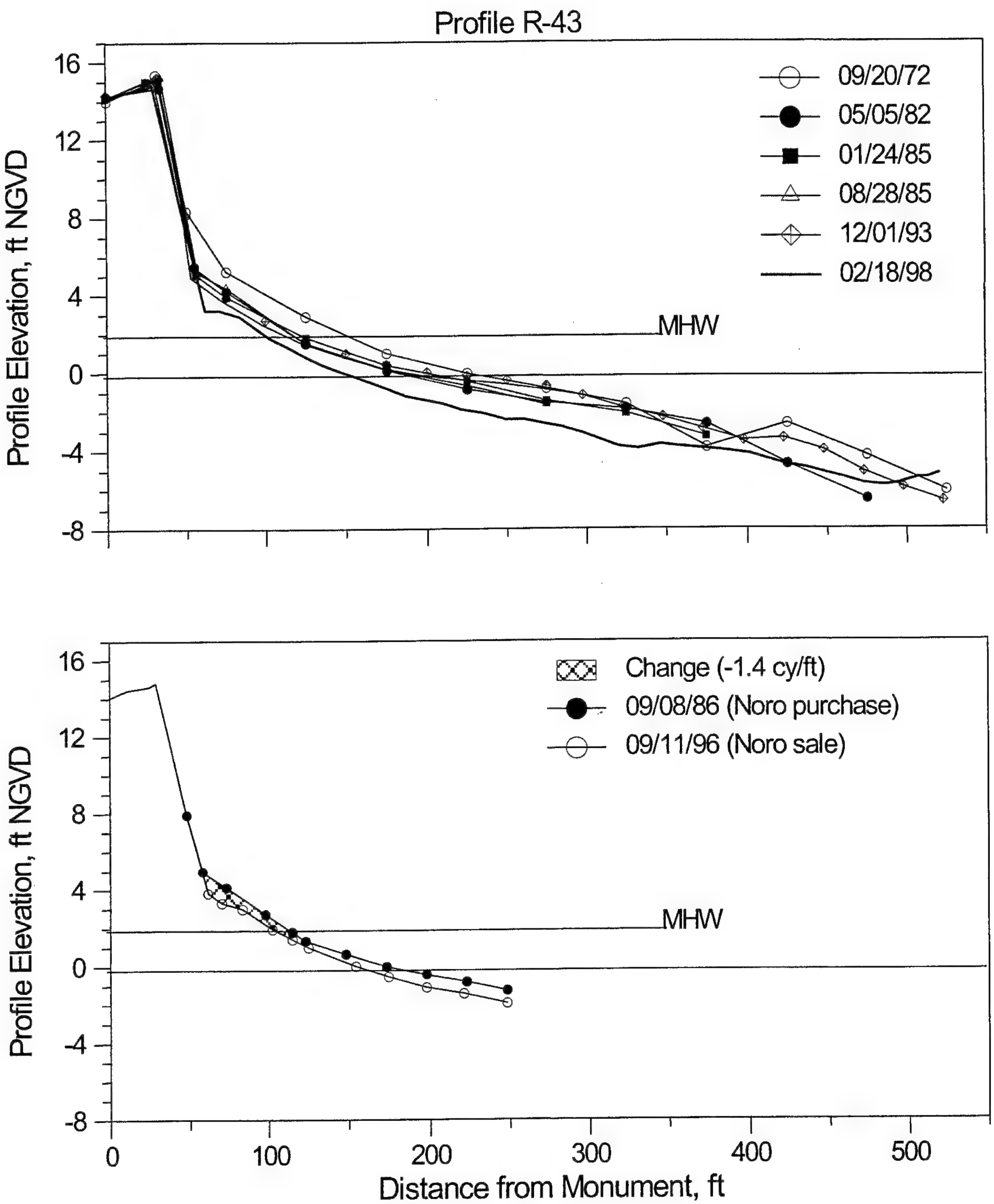


Figure 4-10. Beach-profile surveys at Monument R-43 and calculated volume loss from the time of purchase (August 12, 1981).

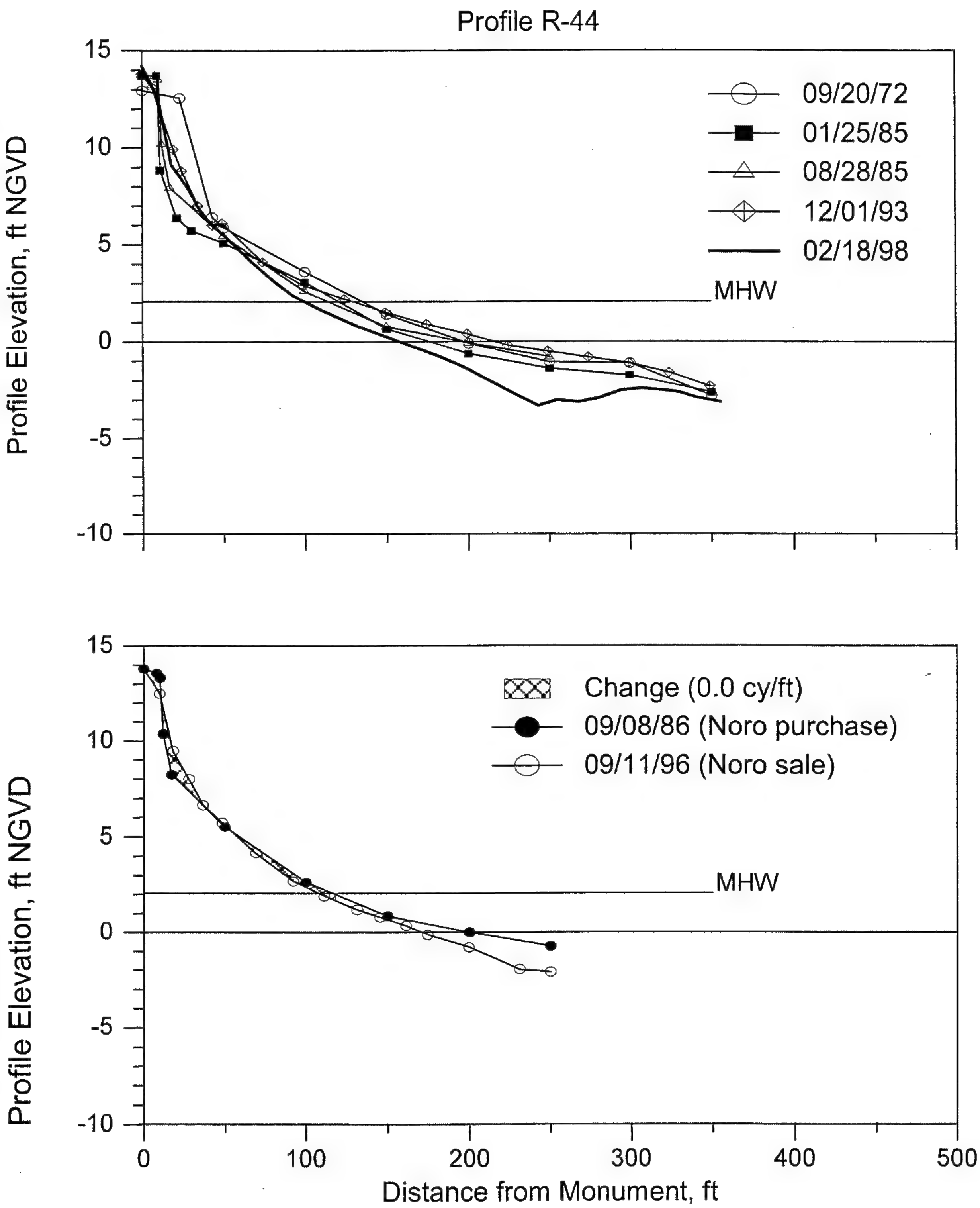


Figure 4-11. Beach-profile surveys at Monument R-44 and calculated volume loss from the time of purchase (August 12, 1981).

5. Summary and Conclusions

The first section of this chapter gives a summary of the overall relevant coastal processes, and the second section summarizes beach and dune change at the properties of the two test plaintiffs, Applegate and Noro. The estimates of the changes were derived from FDEP and USACE beach-profile measurements and from numerical calculations of storm-induced beach and dune erosion as documented and discussed in previous chapters.

5.1. Coastal-Processes Assessment

The primary objective of this assessment was to document the impact of the construction, operation, and maintenance of Canaveral Harbor on the properties of the plaintiffs and to quantify shoreline recession and losses of sand volume associated with beach change (with focus on the properties of the two test plaintiffs). The causes of shoreline erosion and recession were, therefore, identified and quantified. Two hypotheses guided the study approach: (1) the position of the shoreline is primarily controlled by changes in longshore sand transport and, therefore, is influenced by the presence of the Canaveral Harbor entrance and (2) erosion and recession of the beach and dune are primarily associated with storms and cross-shore sand transport. The action and damage produced by storms have a weak, if any, dependence on the presence of the Harbor entrance.

After reviewing pertinent documents and compiling and analyzing existing and new data sets, a determination of Harbor-induced impacts on the beach was derived. Long-term regional changes in the beach were evaluated by analysis of shoreline-position and beach-profile survey data. An assessment of storm-induced erosion of beaches and dunes representative of the conditions at the properties of the two test plaintiffs was also made. The (significant) erosion of the beaches and dunes was estimated by reference to storm information and data. These data were input to a numerical model that calculates storm-induced beach and dune erosion. The extent of Harbor-induced impacts on downdrift beaches was determined with historical shoreline-position data for the period April 1948 to February 1970 for quantifying the response of the natural beach (prior to the major fill of 1974/75). Analysis of NOS data sets by the FDEP and in this study produced the same general trends.

A well-defined zone of shoreline recession, limited to 7,000 ft south of Canaveral Harbor, is associated with the Harbor entrance (1948-1970). A 27,000-ft-long coastal segment south of this point experienced net shoreline advance for the same period, although the magnitude of shoreline advance is calculated in this study to be slightly greater that of the FDEP assessment. Between February 1970 and May 1996, an interval mainly covering a time period after the major 1974/75 USACE beach fill, net shoreline advance was found, illustrating the effectiveness and persistence of the fill over the past two decades.

The position of the HWL was determined for the period September 1972 to February 1998 from FDEP and USACE beach-profile surveys. This information supplemented long-term historical shoreline-position data and revealed beach response to the beach fill of 1974/75 and subsequent shoreline change. Beach and dune erosion and recession were calculated for three storms that struck the coast of Brevard County between 1979 and 1994, a time span that covers the time of ownership of the properties of the two test plaintiffs to the near present.

Four conclusions emerged from the analyses:

1. The sand placed on Brevard County's beaches by the USACE in 1974/75 extended the shoreline seaward of the 1948 (pre-Harbor) shoreline position and seaward of the September 1972 (pre-fill) shoreline position. The 1974/75 beach fill more than compensated for beach erosion that had occurred since the Harbor was constructed. The erosion-impact zone induced by the Harbor that was present on the (natural) beach prior to beach-fill placement was determined to have extended approximately 7,000 ft south of the south jetty. The fill was placed on the beach from the Harbor's south jetty and extended south approximately 10,500 ft. The fill compensated for preexisting erosion over the distance of 7,000 ft, as well as nourished previously accreting areas that are located beyond 7,000 ft south of Canaveral Harbor.

2. The beach in the 7,000-ft erosion-impact zone covered by the fill has experienced erosion since 1974/75. However, the volume of sand placed on the beaches south of the Harbor in 1974/75, and subsequent smaller fills and nearshore placements in the 1990s, had been effective at maintaining the shoreline seaward of its September 1972 position (pre-fill). Therefore, nearly all impacts (beach erosion and shoreline recession) caused by the Harbor relative to pre-fill conditions, have been mitigated by placement of sand just south of the entrance channel.

3. Erosion that developed since the USACE 1974/75 beach fill extends approximately 17,000 ft south of Canaveral Harbor, an increase of about 10,000 ft relative to the southern terminus of the erosion-impact zone that had occurred along the pre-fill (natural) beach. The increased distance of erosion is attributed to adjustments in the beach fill resulting from geometric differences (equilibration of beach slope and spreading loss associated with beach fills) and, possibly, grain-size differences between the natural beach and the engineered beach.

4. Sand-bypassing rates were determined through analysis of long-term sediment transport processes by comparing pre- and post-Harbor bathymetric surveys. Sand bypassing can mitigate or eliminate downdrift beach erosion caused by Canaveral Harbor. Net longshore-transport rates were calculated for the vicinity of the Harbor. The volume of sand deposited along the beach north of the Harbor prior to its construction was subtracted from the volume

of sand that accumulated in the entrance channel and deposited north of the Harbor after its construction, yielding an estimated sand-bypassing rate.

Based on analysis of bathymetric data spanning 65 years, the net sand transport rate near the north jetty was calculated as 308,000 cy/year. The associated sand-bypassing rate was calculated as 155,000 cy/year (taking into account the natural beach deposition rate prior to Harbor construction). Between 1972 and 1997, the USACE placed about 4.0 Mcy of sand on the beaches within 17,000 ft south of Canaveral Harbor, and the shoreline to at least 42,000 ft south of the Harbor experienced net advance. Therefore, the calculated volume of sand bypassing (155,000 cy/year x 25 years = 3.9 Mcy) nearly balances the sediment added to the beach by the USACE between 1972 and 1997.

5.2. Assessment for the Properties of the Test Plaintiffs

The conclusions listed below are based upon analysis of FDEP and USACE beach profile data available at locations adjacent to the properties of the two test plaintiffs, supplemented by numerical modeling of storm-induced beach erosion. Main conclusions are as follows:

1. **Applegate Property.** From August 12, 1981 (time of purchase), to December 8, 1997 (representing the present), the beach eroded and the shoreline receded. At least 95% of sand eroded from the beach fronting the Applegate property was removed from material placed during the 1974/75 USACE beach fill. The natural beach adjacent to the property prior to fill placement just recently began to erode (as shown on the December 8, 1997, beach profile at R-7). From August 12, 1981, to December 8, 1997, the MHW shoreline receded 216 ±7 ft, and the beach eroded 8,500 cy, as determined from beach-profile surveys. These values can be compared with calculation results from storm-induced beach erosion modeling of the cumulative impacts of three of several storms that occurred within this time period. The modeling calculations gave approximately 70 ft of recession and a volume loss attributable to storms of (at least) 3,600 cy. Numerical calculations of storm-induced beach change indicate that at least 42 ±21% of the net erosion that has occurred since the time of purchase can be associated with the impact of severe storms.

2. **Noro Property.** From September 8, 1986 (time of purchase), to September 11, 1996 (representing the time of sale), the MHW shoreline receded 9 ±7 ft, and 80 cy of material were eroded from the beach fronting the Noro property. These small changes are within variability associated with seasonal beach change and do not define a trend. Numerical calculations of storm-induced beach erosion at the Noro property indicate that all net change in sand volume on the upper beach and dune face was caused by storms. Storms are deduced to be the dominant force producing beach and dune change at the Noro property and not blockage of longshore sand transport by Canaveral Harbor.

APPENDIX A. References

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APPENDIX B. Joint Protocol

Applegate et al. v. United States

MEASUREMENT AND ANALYSIS - JOINT PROTOCOL
December 20, 1996 (citation to Addenda added 1/15/97)

This document specifies the manner in which an estimate of the actual and specific losses incurred by the Plaintiffs shall be identified. This Protocol is based on present conditions and conditions at the time of purchase of each property as determined through application of a tier of methodologies described below that are ranked according to degree of accuracy. Losses shall be determined as the change in land area and volume above the mean high water line (MHWL). The Protocol does not distinguish the extent of losses or erosion that may be attributable to the inlet or the losses or erosion that may be attributable to causes independent of the inlet.

All estimates of losses shall be calculated from the date of each Plaintiff's purchase of property until the date of the surveys performed in accordance with this Protocol.

The following is a description of a protocol based on consideration of State of Florida statutes and on the coastal processes and data available for Brevard County:

Current Conditions: (1) A MHWL survey shall be performed for each Plaintiff's property. The surveys shall be performed by using a methodology approved by the Bureau of Survey and Mapping, Florida Department of Environmental Protection (FDEP), pursuant to Florida Statutes, Chapter 177, Part II, the "Florida Coastal Mapping Act of 1974" and Chapter 61G-17-6 Florida Administrative Code. The resultant surveys shall be provided to counsel of the United States and filed with the Bureau of Survey and Mapping. (2) Profile surveys shall be performed at the lateral boundary of each property (see Addendum 1), on each side of all significant discontinuities of dunes, and on each side of shore-parallel and shore-normal protective structures located on the active beach or dune of each property. The maximum lateral distance between profile surveys shall be a hundred feet (100 ft). On each profile survey line, the location and elevation of the dune crest, vegetation line, dune line (top of slope at seaward face of dune), seaward toe of the dune where it meets the beach berm, MHWL, and the locations of other major changes in elevation on the beach above the MHWL shall be surveyed for the property of each Plaintiff by a Registered Land Surveyor. The locations of shore-protection structures and their top elevation shall also be surveyed on each Plaintiff's property.

All elevations shall be referenced to the local National Geodetic Vertical Datum (NGVD) of 1929. With respect to Tier 4 on the attached Table 1, at each FDEP "R" series monument that is located directly north or south of a Plaintiff's property one (1) profile shall be surveyed at each monument. All surveyed profiles will be tied to existing FDEP Coastal Construction Control line monuments utilizing survey traverse lines. Profiles shall include (a) stationing along the profile from the intersection of the profile with a baseline defined as a line connecting the FDEP monuments to the north and south of the property, and (b) associated elevations at a minimum

spacing of twenty feet (20 ft) on center and at breaks in slope from the baseline to wading depth—at least seaward of elevation 0.0 ft NGVD. All profiles shall be surveyed at the same magnetic bearing as those profiles surveyed historically by FDEP at the same monument or at surrounding monuments as appropriate. The closure accuracy of the horizontal control traverse shall meet or exceed 1 part in 20,000. The profile shall be surveyed using a calculated angle turned off the traverse line based on an average bearing of the historic profiles for the two adjacent R-monuments located north and south of the subject tract. All benchmarks used shall be Third-Order, Class-I accuracy or better. All vertical control will be based on closed bench runs through at least two control monuments. The "shoreline" shall correspond to the MHWL as determined by the FDEP Bureau of Surveying & Mapping in accordance with Chapter 177 Part II.

Purchase Conditions: Estimated conditions at the time of purchase of the property of each Plaintiff shall be calculated by using the highest possible tier of methodologies as listed in Table 1 and Addendum 2.

Losses: Estimated losses that have occurred at the property of each Plaintiff shall be determined in the form of "loss of land" and in the form of "volumetric loss" from the beach and dune as determined by the Current Condition and the Purchase Condition. Loss of land shall be prescribed as the area in square feet calculated from the average change in MHWL position multiplied by the frontage of the property (Addendum 2). Where topographic data exist, volume losses shall be calculated by spatially weighted average end methods. Where topographic data do not exist, volume losses shall be calculated based on the change in average position of the MHWL and assumed profile shapes.

Documentation: For each Plaintiff's property, documentation of the results of the application of the above-described Protocol shall include the following:

1. A plan view depiction showing to scale;
    a. Current conditions as surveyed;
    b. Purchase conditions including the historical data characterizing the conditions;
    c. State Plane Coordinate reference grid;
2. Cross sections depicting the profile data used to determine volumetric changes;
3. Ground-level photograph of the subject property;
4. Narrative description of the application of Protocol; and
5. Copies of surveys and/or aerial photographs used to establish purchase conditions.

Nothing herein constitutes an admission of liability by defendant or acknowledgment by defendant of any loss.

Table 1. Tiers of Joint Protocol for determining location of the mean high water line (MHWL) and the dune-beach cross section at time of purchase.		
Tier	**MHWL**	**Cross Section**
	Tier 1 (surveys within 2 months)	
1A	State-approved MHW boundary survey of property within ±2 months of purchase date.	Topographic survey of property within ±2 months of purchase date.
1B	Controlled beach-profile survey through subject property within ±2 months of purchase date of subject property.	Controlled beach-profile survey through subject property within ±2 months of purchase date of subject property.
1C	State-approved MHW boundary survey of a neighboring property within ±2 months of purchase date of subject property.	Topographic survey of a neighboring property within ±2 months of purchase date of subject property.
1D	Controlled beach-profile survey through neighboring property within ±2 months of purchase date of subject property.	Controlled beach-profile survey through neighboring property within ±2 months of purchase date of property.
	Tier 2 (surveys within 6 months)	
2A, 2B, 2C, 2D	Same as Tier 1, within ±6 months.	Same as Tier 1, within ±6 months.
	Tier 3 (surveys within 1 year)	
3A, 3B, 3C, 3D	Same as Tier 1, within ±12 months	Same as Tier 1, within ±12 months
	Tier 4 (Interpolation beyond 1 year)	
4	If data for a subject property are not available to meet the quality and time criteria of Tier 1 through Tier 3, then either or both of the following shall be used by temporal and spatial interpolation to establish conditions at purchase as follows: (a) two sets of profile or shoreline surveys (or a combination) on the subject or neighboring properties [Known sources of data include profile and historical shoreline data maintained by the FDEP.], (b) aerial photographs [Known sources and dates of aerial photographs are U.S. Department of Agriculture, 1951; FDEP, 12/72, 05/74, 05/80, 06/80, 07/80, 10/85, 11/85; Olsen Associates, Inc., 11/93, and U.S. Army Engineer District, Jacksonville, 12/93.] The basis of the data set selection shall be included in the documentation.	

Table 2. Notes to Table 1 for the tiers of Joint Protocol.	
No.	**Note**
1	The highest tier, according to the availability of data, shall be followed. Any exceptions to the Protocol shall be cited in the documentation with a description of the basis of the exception.
2	For determining the location of the MHW boundary on subject properties from beach-profile surveys on neighboring properties, the MHW elevation shall be established on the beach-profile surveys and interpolated between them.
3	Controlled profile-survey data sets of variable coverage are available from the following sources for the specified dates: FDEP, 09/72, 11/73, 09/79, 11/81, 05/82, 07/83, 01/85, 03/86; 11/93; and U.S. Army Corps of Engineers, Jacksonville District, 12/93.
4	For use of data from neighboring properties, the neighboring property must be located within ±1000 ft. of the subject property, and documentation shall be provided to demonstrate the subject and neighboring properties possess similar conditions (e.g., presence of armoring, beach fills, dune height).
5	If the neighboring properties possess different characteristics, for example, one is armored and the other is not, then a rational analysis procedure shall be applied and documentation provided to transfer the location of the MHW line from one to the other. For example, the relationship in positions of the MHW boundary at the two properties in the Current Condition could be used.

ADDENDUM 1: CURRENT CONDITIONS

ADDENDUM TO THE MEASUREMENT AND ANALYSIS JOINT PROTOCOL PROVIDING A METHODOLOGY FOR DETERMINING THE APPROXIMATE LOCATION OF THE NORTH AND SOUTH BOUNDARY LINES OF THE PROPERTY OWNED BY THE PLAINTIFFS.

Determining the approximate locations of the North and South boundary lines for the purpose of performing beach-profile surveys is necessary. To accomplish this task in an efficient and cost-effective manner, the location of physical improvements such as roadways, buildings and other structures, fences, walls, hedgerows, and other indications of possession as a basis of measurement or the property boundary in question will be utilized. Measurements will be performed using record dimensions from the deed descriptions and plat references and scaled dimensions from the tax assessor's maps or aerial photographs of the area. This methodology will place the profile lines in close proximity to the actual property boundaries (about ±2 ft). All profile lines will be located in reference to the Florida Department of Environmental Protection's Coastal Construction Control Line (CCCL). If property boundaries cannot be determined in this manner by visual inspection, then a boundary survey will be performed in accordance with Florida Statute.

ADDENDUM 2: DETERMINING PROPERTY WIDTH

ADDENDUM TO THE MEASUREMENT AND ANALYSIS JOINT PROTOCOL PROVIDING A SET OF TIERS FOR DETERMINING PROPERTY WIDTH FOR CURRENT CONDITIONS AND LOSSES.

Volume and area computations will be performed utilizing the deed or plat dimensions or, if a previous survey record is available, survey dimensions would be utilized in accordance with the following order:

Tiers of Protocol for Determining Property Width	
1	Available survey data
2	Deed dimensions or dimensions from record plat referenced in deed
3	Dimensions from tax assessor's maps

APPENDIX C. Storm Data

Table C-1 gives a detailed chronology of storms to impact the Brevard County Coast.

Table C-1. Chronological summary of identified storms impacting Brevard County beaches.

SOURCES OF DATA:

a. Balsillie, J.H. 1985. "Post Storm Report: The Florida East Coast Thanksgiving Holiday Storm of 21-24 November 1984," Post Storm Report 85-1, FDNR, DBS
b. USACE 1967. "Beach Erosion Control Study on Brevard County, FL," U.S. Army Engineer District, Jacksonville, FL
c. USACE 1996. "Brevard County, FL, Shore Protection Project Review Study, Feasibility Report with Final Environmental Impact Statement," U.S. Army Engineer District, Jacksonville, FL
d. USACE 1961. "Survey Report Analysis of Hurricane Problems in Coastal Areas of Florida"
e. Hunt, S.D. 1980. "Port Canaveral Entrance, Glossary of Inlets Report No. 9," Florida Sea Grant College Report No. 39, Department of Coastal and Oceanographic Engineering, Univ. of Florida, Gainesville, FL
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g. WXP, The Weather Processor WWW Server, Purdue University, website: http://wxp.atms.purdue.edu/hurricane/atlantic/index.html
h. Balsillie, J.H. 1985. "Calibration Aspects for Beach and Coast Erosion... "
i. Scheffner, N.W. et al. 1994. "A Tropical Storm Data Base for the East and Gulf of Mexico Coasts of the U.S.," Dredging Research Program Report DRP-1-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS
j. Melbourne, Florida, Public Library - Archived Newspapers Section
k. National Weather Service, Melbourne, FL, website - http://sunmlb.nws.fit.edu
l. National Oceanic and Atmospheric Administration, National Hurricane Center website - http://www.nhc.noaa.gov

DATES ARE PRESENTED IN YYYYMMDD FORMAT

TYPE OF STORM: **TC** - Tropical cyclone (i.e., hurricane, tropical storm, or tropical depression)
NE – Northeaster

SOURCES	DATE	TYPE	INFORMATION
c,e,i	18990803	TC	Hurricane skirted the Atlantic Coast of Florida from south to north.
c,i	19010804	TC	Hurricane landfall near Ft. Lauderdale, entered Gulf at Sarasota.
d,e,i	19030909	TC	Hurricane landfall between West Palm Beach and Ft. Lauderdale, entered the Gulf through Tampa Bay.
d,e	19060614	TC	Hurricane landfall in SW Florida, entered the Atlantic at Stuart.
d	19090827	TC	Hurricane skirted east coast of Florida from south to north, passed directly over Cape Canaveral.
d	19090922	TC	Tropical Storm landfall in SW Florida, entered the Atlantic near Cocoa Beach.
b,c,i	19101009	TC	Hurricane landfall in SW Florida, entered the Atlantic near Jacksonville.
d	19150801	TC	Hurricane tracked northwest along the East Coast and made landfall at Daytona Beach.
d	19160821	TC	Hurricane skirted east coast of Florida from south to north.
d	19160909	TC	Tropical storm tracked to northwest Florida along the East Coast and made landfall in Port Canaveral area.
b,d,e,i	19211021	TC	Hurricane landfall at Tampa, entered the Atlantic near New Smyrna Beach.

SOURCES	DATE	TYPE	INFORMATION
d,e	19251129	TC	Hurricane landfall in SW Florida, entered Atlantic between St. Augustine and Daytona.
b,c,d,e,i	19260722	TC	Hurricane skirted Florida Atlantic Coast from West Palm Beach to landfall at Cape Canaveral.
c,d,i	19260911	TC	Hurricane landfall at Miami, entered the Gulf near Ft. Myers.
c,d,e,i,j	19280803	TC	Hurricane landfall at Ft. Pierce; *Melbourne Times Journal (MTJ)* reported 60-mph winds, slight local damage.
b,c,d,e,i,j	19280906	TC	Hurricane landfall at West Palm Beach; *MTJ* reported local wind measurements of 60 to 75 mph.
c,d,i	19290922	TC	Hurricane brief landfall along the southern tip of the Everglades, skirted the Gulf Coast, and entered mainland at Apalachicola.
d	19310902	TC	Hurricane landfall in SW Florida, entered Atlantic near Stuart.
b,j	19321201	NE	Northeaster, *MTJ* reported "The greatest damage in this section occurred at Melbourne Beach where the ocean washed away the bank in front of eight houses. The bluff, said to be 18 ft high, was cut into for a distance of about 15 ft almost to the front porches of the buildings in that section. ... It became necessary to brace the houses belonging to S.E. Hilles, C.E. Gray and E.V. Johnson as the water was beginning to undermine front pilings. The Rice and Timney homes were the least damaged of any, but practically all of the front yard of the O'Conner property was lost and the sidewalk fronting some of the places was destroyed. No damage was reported at the casino although E.H. Dennis, manager, said Thursday that the water came almost to the front side of the building." Other sources reported a 3-ft drop in beach elevation.
d,e,i	19330725	TC	Hurricane landfall at Ft. Pierce, entered the Gulf at Sarasota.
c,d,e,i,j	19330831	TC	Hurricane landfall at West Palm Beach, northwestward track to Cedar River area; *MTJ* reported 60-mph winds in Melbourne and evidence of sand-covered lawns at Melbourne Beach (i.e., evidence of overwash).
c,i,j	19350829	TC	Hurricane skirted Gulf Coast of Florida from south to north, landfall near Steinhatchee; devastated Keys.
c,d,i,j	19351030	TC	Hurricane landfall at Miami, followed a southwestward track through the Everglades into the Gulf.
d	19360926	TC	Hurricane landfall near Cocoa Beach.
d	19370828	TC	Tropical storm tracked northwestward along the East Coast and made landfall at Daytona Beach.
d,e	19390807	TC	Hurricane landfall at Stuart.
c,d,e,i,j	19441012	TC	Hurricane landfall at Venice, followed north-northeastward track and entered Atlantic at Jacksonville; *MTJ* reported "63-mile (per hour) sustaining wind was recorded. Gusts are said to have reached as high as 80 miles as hour. The ocean was rough with high seas pounding the beach washing sand on the streets near the Bahama Beach Club."
d,e	19450620	TC	Hurricane exited Florida near St. Augustine.
d,e,i	19450912	TC	Hurricane landfall south of Miami, entered the Atlantic near St. Augustine.
c,i,j	19470904	TC	Hurricane landfall near West Palm Beach, followed a westward track and entered the Gulf near Naples; *MTJ* reported 85-mph winds.
b,j	19470919	NE	13-day storm duration; *MTJ* reports 85-mph winds on 19 Sep 1947; severe erosion reported; dune recession averaged 25-30 ft at Patrick AFB south shore.
d	19480510	TC	Tropical storm tracked northward along the East Coast and passed directly over the tip of Cape Canaveral.
c,d,e,i,j	19480918	TC	Hurricane landfall at peninsula's southwest tip; northeastward track led to Atlantic entry near West Palm Beach;

SOURCES	DATE	TYPE	INFORMATION
			MTJ reported maximum winds of 88 mph at Melbourne.
c,d,e,i,j	19490823	TC	Hurricane landfall at West Palm Beach, then tracked up the peninsula; *MTJ* reported minimal damages and no mention of erosion.
d,e,i	19500901	TC	Hurricane Easy, landfall near Crystal River; eastward track to Daytona area, then northwestward.
b,c,d,e,i,j	19501013	TC	Hurricane King, landfall at Miami, tracked straight up long axis of the peninsula; *MTJ* reported 55-mph sustained winds, 71-mph gusts; tides 3-4 ft above normal, minor beach erosion along entire county.
e,f	19510516	TC	Hurricane Able.
d,f	19511001	TC	Hurricane How landfall in SW Florida, entered Atlantic at Vero Beach.
e	19520818	TC	Hurricane Able.
b,f,j	19521021	NE	Northeaster, *MTJ* reported 48-mph sustained winds, 62-mph gusts; photo shows bulkheaded dune - evidence of erosion prior to Port construction. Excerpt: "The Atlantic Ocean took its load of sand off the beach too. At one spot in Melbourne Beach it was figured that the rough ocean yesterday lowered the beach approximately 2 ft or more, according to the original line of the beach marked on posts left of a smashed breakwater. The beach was pushed back to property lines all along the ocean front, but no great amount of land was believed lost to the angry ocean."; and on 27 Oct 1952: "The Atlantic Ocean is claiming its toll of land all along the beach in the area. After Tuesday's storm it was estimated that the beach was lowered by approximately two ft. However, because heavy seas prevailed since that time the beach level has been estimated to be an additional 2 ft lower. The 4 ft of the beach has been taken away by the sea is shown by posts left of broken breakwaters." It was reported that a portion of a parking lot at Patrick AFB was undermined.
c,d,f,i,j	19531007	TC	Tropical Storm Hazel, landfall at Tampa, tracked eastward across the State and entered the Atlantic at Melbourne; *MTJ* reported 35- to 45-mph winds with gusts to 62 mph; little damage in Melbourne area.
f,i	19540826	TC	Hurricane Carol followed a northward track, hundreds of miles east of the Atlantic Coast.
f	19540906	TC	Hurricane Edna.
f,i	19541005	TC	Hurricane Hazel (II) followed a northward track, hundreds of miles east of the Atlantic Coast.
f,j	19561030	TC	Hurricane Greta; on 06 Nov 1956, *MTJ* printed a photograph of beach erosion with caption, "Indialantic's beach washed away - This picture taken yesterday afternoon shows what the past few day's high tides have done to the beach. The sands, which were leveled off by a bulldozer only a few days ago, were washed back out into the surf by the exceptional tides. Harry Geiger, Indialantic police commissioner estimated it might take some six months for the sands to return to normal. The pilings and culvert pictured exposed were entirely under the sands a few days ago. Plans are being considered to take the pilings out completely."
b,f	19561100	NE	Northeaster, 4-day duration, tides 4 ft above normal, Melbourne Beach eroded 3 ft, bulkhead damaged at Patrick AFB.
f	19580808	TC	Tropical Storm Becky.
f,i	19580824	TC	Hurricane Daisy followed a northward track, hundreds of miles east of the Atlantic Coast.
f	19581005	TC	Hurricane Janice.
d,f,i	19590617	TC	Unnamed Hurricane landfall at Tampa, tracked across the peninsula and entered Atlantic just north of Cape Canaveral.

SOURCES	DATE	TYPE	INFORMATION
f,i	19590920	TC	Hurricane Gracie followed an erratic northward track, hundreds of miles east of Atlantic Coast.
d,f	19591017	TC	Hurricane Judith landfall in SW Florida, tracked northward and entered the Atlantic at Vero Beach.
d,f	19600728	TC	Tropical Storm Brenda.
b,e,f,i,j	19600829	TC	Hurricane Donna landfall near Naples, then tracked north and east across the peninsula to enter the Atlantic between St. Augustine and Daytona. *MTJ* reported 75-mph winds at Melbourne during height of the storm.
d,f,j	19600917	TC	Tropical Storm Florence landfall in SW Florida, tracked eastward to Stuart, turned back to the west, and reentered the Gulf at Tampa.
b,f	19600900	NE	Some seawall damage at Patrick AFB.
b,e,f,h,j	19620305	NE	Northeaster, Fair Weather/Ash Wednesday storm, severe damage in southern Brevard County; 11 Mar 1962 *MTJ* photo shows work crews at Patrick AFB picking up pieces of Patrick AFB fishing pier, which had drifted to shore after the pier was damaged.
f,i	19620826	TC	Hurricane Alma tracked northward from Miami area, brushed the coastline near West Palm Beach, and moved northeastward, paralleling the Atlantic coastline.
f,j	19621014	TC	Hurricane Ella; *MTJ* published photo of Indialantic motel with caption: "Men Against the Sea - The precarious angle of the seawall at the Tideland Motor Inn is shown here as workmen toiled far into the night to fight the heavy seas stirred up by Hurricane Ella that threatened to wash away the wall and cause heavy damage to the building." The accompanying article read: "No Hope Seen for Hotel, Seas Win Fight." A 21 Oct 1962 article reported "A hurricane-tossed Atlantic Ocean claimed the rear section of the restaurant at the Tidelands Motel at 1:30 p.m. yesterday and residents of an adjacent building made a hasty evacuation in expectation of continued heavy seas last night." Accompanying photos show wave uprush to the base of a damaged seawall at the Sea Nymph Motel and damage to the Tidelands Motel and adjacent beach.
e,f	19621126	NE	Northeaster.
k	19630203	NE	Northeaster, "continuous strong northeast winds produced by a low pressure area east of FL coast generate- high tides, rough surf and coastal flooding along entire northeast Florida coast from Nassau to Brevard Counties. Beaches sustained considerable erosion damage and some beach properties and roads were undermined. Damage was greater than expected as beaches had not been repaired from damages inflicted by a smaller storm in December 1962."
f	19630330	NE	Northeaster.
j	19630924	TC/NE	*MTJ* reported "Heavy seas and gales battered East Coast Florida beaches today as the season's first cold front slipped down the peninsula. At the same time, the Weather Bureau checked on two suspicious tropical disturbances. ... There have been some reports of beach erosion by high tides running three feet above normal, ... In Cocoa Beach, the area in front of the Holiday Inn, Ramada Inn and Schrafft's Carriage House was inundated, ... Cocoa Beach Fishing Pier managed to withstand the sweep of the raging seas, but the collapsed, from severe beach erosion in Melbourne beach, dwellings threatened. Patrick AFB pier lost another few feet out at the end."
f	19631004	NE	Northeaster.
e,f	19631016	TC	Hurricane Ginny approached the Florida coast from the northeast, after an erratic change of direction near Cape Hatteras. When it reached an area about 200 miles east of Cape Canaveral, the storm turned northward and paralleled the Atlantic coastline, never making landfall

SOURCES	DATE	TYPE	INFORMATION
b,c,e,f,i,j	19640820	TC	Hurricane Cleo landfall at Ft. Lauderdale, then tracked up the entire length of Florida's east coast. Patrick AFB reported maximum winds of about 65 mph.
e,f,i	19640828	TC	Hurricane Dora landfall near St. Augustine, then tracked westward across Florida.
e,f,i	19641008	TC	Hurricane Isabel landfall along SW Florida, tracked northeastward and entered Atlantic near West Palm Beach.
b,f	19641000	NE	Northeaster with moderate to severe beach erosion; beach and dune erosion reported north of Cape Canaveral on NASA property.
e,f,i	19650827	TC	Hurricane Betsy tracked from east to west brushing the tip of the peninsula; estimated storm surge of 1.5 ft in vicinity of the cape.
f,i	19660604	TC	Hurricane Alma skirted the west coast of Florida from south to north before making landfall at Apalachicola.
f,i	19660921	TC	Hurricane Inez approached from the Bahamas along a westward track, just brushing the southern tip of Florida.
f,i	19670907	TC	Hurricane Doria originated near Bermuda and originally tracked southwestward toward West Palm Beach; about 100 miles offshore, the storm did a 360-degree turn and headed back out to sea.
c,f,i,j	19680601	TC	Hurricane Abby landfall near Ft. Myers, crossed the peninsula and entered Atlantic near Vero Beach, then turned northwestward and brushed the East Coast from Cape Canaveral to Jacksonville, where it made its second landfall. *MTJ* reported 50-mph winds while offshore of Melbourne.
f	19680617	TC	Hurricane Brenda.
f	19680809	TC	Hurricane Dolly.
e,i	19681013	TC	Hurricane Gladys landfall near Crystal River and entered Atlantic at Jacksonville.
f,i	19690821	TC	Hurricane Gerda landfall at West Palm Beach, turned northeast and entered the Atlantic at Melbourne.
f	19691001	TC	Tropical Storm Jenny.
f	19691007	TC	Hurricane Kara.
f	19710810	TC	Hurricane Beth.
f,i	19710820	TC	Tropical Storm Doria stayed well east of the Bahamas and tracked northward to Cape Hatteras.
f	19720829	TC	Tropical Storm Carrie.
f	19720904	TC	Hurricane Dawn.
e,j	19730221	NE	Northeaster, Lincoln's Birthday storm; extensive beach erosion along entire eastern coastline; dune overtopping; a *MTJ* report entitled "Erosion Guts Beach, but Sand's in Ocean" states that "Natural sand flow from the north piles up about 300,000 cubic yards of sand against the Port Canaveral jetty and in the Port's channel each year. And twice each year, a seagoing dredge pumps up the sand and dumps it at sea while putting the finishing touches on an 'emergency' project to restore the dune line at Adams Avenue in Cape … portions of Cape Canaveral's beach washed away", Maclay said. A bridge was built over the dunes so people would not trample paths through the restored dunes. "On Adams Avenue in a 48-hour period, they lost 32 ft of beach," County Commissioner John Hurdle said". A 22 Feb 1973 *MTJ* article states that "Cape Canaveral has lost up to 80 ft of beach and perhaps more in places from recent storms, a map of the city's dune line released Wednesday revealed. The map was delivered to city officials by Tom Strang ... for Briley, Wild and Associates, the city's consulting engineers. 'In the worst area, it was approximately 80 ft and in the least area approximately 20 ft,' Strang said. The map was surveyed in 1972 and portions of the city's beach were resurveyed this month after a series of 'northeastern'

SOURCES	DATE	TYPE	INFORMATION
			storms washed away enormous quantities of sand and threatened three city streets which dead end at the ocean, Strang said. The map also shows dune lines for 1951 and 1966 as being hundreds of feet east of their present locations."
e,f,j	19731016	TC	Tropical Storm Gilda resulted in tides running 4-6 ft above normal. Significant damage to Brevard County beaches. A series of *MTJ* articles on beach erosion ran 22-31 Oct 1973. Photos show collapsed bulkheads and seawalls. Excerpts include "Heavy pilings were snapped like matchsticks by the weight of water soaked sands behind them as the seas washed away the supporting sand in front. At Second Avenue, the concrete steps leading to the beach hung in the air. ... It was more than eight feet from the bottom step to the waves that lashed at the base of the supporting bulkhead. The endangered homes were built years ago before adoption of State and City regulations, which now forbid construction on top of the ocean bluff line. ... Asking that Gov. Rueben Askew go along with declaring the beaches from Patrick AFB to Sebastian Inlet a disaster area."
e,j	19741004	TC	Tropical Depression Number 4, caused severe flooding and erosion. Tides 3-5 ft above normal and gale force winds were reported. A series of *Florida Today* articles dated 5-8 Oct 1974 document the erosion. Excerpts include headline "Cape Canaveral Site Crumbles - Beach House Perishes - The Applegate house came crumbling down Sunday morning. Ocean waves which had been eating away at the beach and foundation beneath the structure for more than five years finally did the house in at 11:30 a.m." A photo is included with caption "Crashing waves pound against the Applegate House in Cape Canaveral, demolishing part of the structure." The partially completed beach fill berm suffered maximum erosion of 25 ft, average erosion of 7 ft.
f	19750629	TC	Tropical Storm Amy.
f	19750726	TC	Hurricane Blanche.
f	19751001	TC	Hurricane Gladys.
c,j	19780205	NE	Northeaster; *Florida Today* reported northeast winds 15-20 mph with gusts to 32 mph.
c,j	19781017	NE	Northeaster; *Florida Today* reported sustained northeast winds of 25 knots.
j	19781230	NE	Northeaster documented in *Florida Today* article dated 30 Dec 1978, "Beaches Suffer Scrapes - High pounding waves have eaten away up to three feet of Space Coast beaches in the past three days." Northeast winds 20-25 knots, 8- to 12-ft seas, 4- to 6-ft surf.
c,j	19790218	NE	Northeaster; *Florida Today* reported northeast winds 20-30 knots, 8- to 12-ft seas, 2- to 3-ft surf.
c,i,j	19790825	TC	Hurricane David landfall near Ft. Pierce, then skirted the East Coast. A 05 Sep 1979 *Florida Today* article reported "Hurricane David stripped three to four feet of sand from some Space Coast beaches, leaving the most severe damage in south Brevard and Indian River County, but authorities said the erosion could have been much worse." Other articles and photos describe damages in Brevard County.
c,j	19791104	NE	Northeaster; *Florida Today* reported northeast winds 10-25 knots, 6- to 9-ft seas, 3- to 4-ft surf.
c,j	19801221	NE	Northeaster; *Florida Today* reported northeast winds 15 mph, 3- to 4-ft waves.
g,i	19810807	TC	Hurricane Dennis landfall along the SW coast of Florida, then tracked northward and entered Atlantic near Cape Canaveral.
g,i	19830823	TC	Hurricane Barry tracked from a point north of Bahamas, due west to landfall near Melbourne.
c,j	19840101	NE	Northeaster; *Florida Today* reported 15- to 20-mph winds, 40-mph gusts, 12- to 14-ft seas.

SOURCES	DATE	TYPE	INFORMATION
g,i	19840908	TC	Hurricane Diana tracked slowly as a tropical storm, approaching Cape Canaveral from the east, then turned northward approximately 100 miles offshore and proceeded on a northeastward track.
a, j	19841124	NE	Northeaster/Thanksgiving Day storm - extensive Space Coast damage documented in area newspapers; 24 Nov 1984 article includes photograph of Noro property with caption "Pelican Landing Resort in Cocoa Beach hangs over dune's edge...tides high waves ate away at building's foundation." "Beaches in Brevard...took their worst beating in a decade from Friday's stormy one-two punch of winds and waves, officials said. ...Norene Jaynes, owner of the Pelican Landing apartment complex at 1201 S. Atlantic Ave., Cocoa Beach, saw her 12-unit complex's foundation hanging dangerously over an eroded beach Friday. "When I heard about it, I thought maybe the steps would be gone and maybe a little sand had trickled from behind the sea wall," she said. "But this is incredible." (Mayor Bob) Lawton said the coastal damage was the worst he could recall, much worse than any hurricane in recent memory. 25 Nov 1984 photo with the caption "Bulldozer pushes dirt back into place around base of Pelican Landing in Cocoa Beach." "The city gave the coastline hucksters carte blanche when it came to destruction of the dunes, the final barrier and Mother Nature's protective shield. Too late! It's all gone." Numerous other articles describing extensive damages and efforts to rebuild.
c,j	19850915	NE	Northeaster documented in *Florida Today* article "Weekend winds, waves gnaw at beaches – Seven- to ten-foot waves driven by 25-mph northeasterly winds pounded Space Coast beaches this weekend, causing some mild erosion, officials said. Brevard County escaped serious erosion problems ..."; however, a19 Sep 1985 article with photos depicts extensive damages at Satellite Beach.
c,j	19860109	NE	Northeaster documented in *Florida Today* article "Storm nibbles beach; damage reported at Patrick AFB where a $1.4 million restoration project is under way to renourish beaches damaged during the Thanksgiving Day storm... Between 5 and 10 percent of the 90,000 cubic yards of sand placed on the shoreline south of Cocoa Beach were either washed away or shifted to other areas..."
c,j	19860322	NE	Northeaster; *Florida Today* published reports of 30-ft offshore waves; gusts to 40 mph.
c,j	19861018	NE	Northeaster; *Florida Today* reported northeast winds 15-20 mph.
c,j	19861205	NE	Northeaster; *Florida Today* reported northeast winds 15-20 knots, 4- to 6-ft seas.
c,j	19870107	NE	Mild northeaster; *Florida Today* reported northeast winds of only 10 mph, 3- to 4-ft seas.
g	19880821	TC	Tropical Storm Chris.
c,j	19890311	NE	Northeaster documented in *Florida Today* article "Weather wreaks havoc on beaches"; "The effects of the storm ...; In Cape Canaveral as much as 10 ft of dune line washed away at Cherie Down Park...; The weeklong blast of cold, stormy weather are almost as bad as the damage done by the 1984 Thanksgiving at Ocean Avenue beach access, a wall of sand seven feet high stretched away on either side of the stairs leading to the surf. Park Ranger Joan Reader said the county closed the beaches because the sand had been dragged away, unearthing long-buried slabs of broken concrete. "It looks like the Roman ruins."; Smith said broken slabs of concrete, taken from a large pile of refuse unearthed by the winds and waves, under the stairs. On one piece of concrete someone had scratched "Frank Alma, 1-8-60." A 13 Mar 1989 article states "Playa Linda Beach received so much damage that it will be closed two to three weeks for repairs... "The sand out there is just down to barren rock," said Sibbald Smith...; Fifteen of Playa Linda's 18 stairways were torn apart, and up to two-thirds of its dunes disappeared Friday, when the storm peaked ...; "...90 percent of the sand in a renourishment project at Sebastian Inlet washed away"; "Melbourne Beach lost four to five feet of beach ..."; "Satellite Beach lost one to three feet of beach ..."

SOURCES	DATE	TYPE	INFORMATION
			Sustained NE wind speeds of 30 to 40 knots were reported, with 10- to 15-ft surf.
g	19890910	TC	Hurricane Hugo.
c,j	19930318	NE	Northeaster; *Florida Today* reported northeast winds 20 knots and 5- to 7-ft seas.
k	19940218	NE	Northeaster, onshore winds 30-40 mph with gusts to 55 mph caused beach erosion and minor coastal flooding; greatest damage along coast from Brevard to Palm Beach counties, where some beach front homes were nearly undermined.
j,k	19941108	TC	Tropical Storm Gordon; 15 Nov 1994 *Florida Today* article "Gordon bites into beaches" stated "The beaches at Washington and Fillmore avenues, which are eight blocks apart, had lost 9 ft of coastline over the weekend ..."; Photo of Applegate property. "...In three decades, the ocean has gobbled 300 feet of beach at the spot, undercutting part of the home and forcing city officials to condemn it.". A 16 Nov 1994 article shows workers at Patrick AFB and states "... waves from TS Gordon have chewed off some beach crosswalks and taken as much as 3 feet of dune in some places, said Mark Crossley..."
j	19950731	TC	Hurricane Erin; 04 Aug 1995 *Florida Today* article "Storm mauls beaches" stated "Hurricane Erin swiped as much as 8 feet of sand off some Brevard County dunes. ... worst erosion in Satellite Beach and Indialantic. ... In a few sections of Cocoa Beach, surges deposited sand on dunes. ..."; Photo with caption "Dunes at Shepard Park in Cocoa Beach buried fences because they were piled so high from the wind."
j	19950824	TC	Tropical Storm Jerry; 25 Aug 1995 *Florida Today* article "Residents wage costly battle against erosion" stated "Hurricane Erin and TS Jerry have eroded almost 10 feet of beach near Diener's Satellite Beach home."
l	19960617	TC	Tropical Storm Arthur, tracked northward approximately 200 miles off the Atlantic Coast of Florida.
g,j	19960711	TC	Hurricane Bertha, tracked northward several hundred miles offshore, paralleling the Atlantic Coast.
l	19960904	TC	Hurricane Fran, as a Category 3 hurricane, passed Cape Canaveral approximately 340 miles offshore.

Appendix D: Photographs

This appendix contains photographs documenting the physical condition of the beach and structures along Brevard County and the properties of the test plaintiffs, Don and Gale Applegate and Noro and Company.

Figure D-1: View north along the concrete bulkhead at the Officers Club, Patrick AFB, February 20, 1997 (source: N. C. Kraus).

Figure D-2: Canaveral National Seashore at the Brevard/Volusia County line on September 6, 1979, showing storm damage to the dunes from Hurricane David (source: USACE, Jacksonville District).

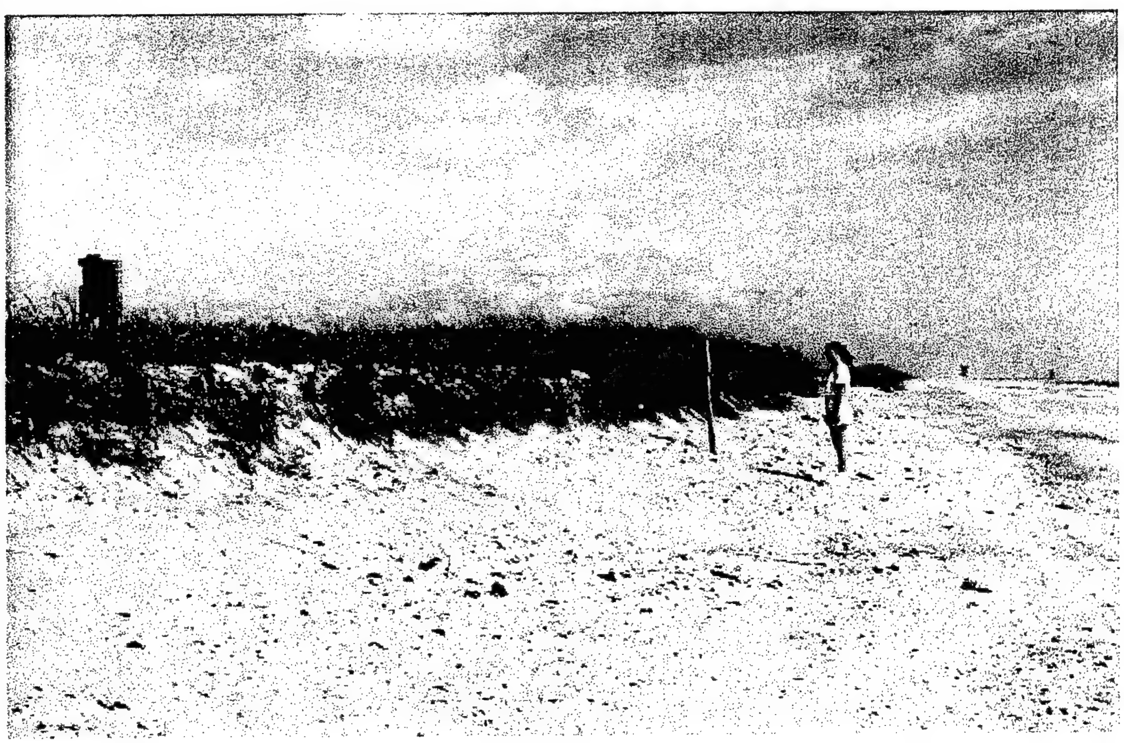

Figure D-3: NASA Federal Property at the tip of Cape Canaveral on May 10, 1996. Damage to the dunes from past storms is still visible (source: N. C. Kraus).

Figure D-4: View of Jetty Park just south of the South Jetty on May 9, 1996. A beach nourishment project was constructed in January 1996 (source: N. C. Kraus).

Figure D-5: View of Jetty Park south of the South Jetty on February 20, 1997; one year after beach nourishment project (source: N. C. Kraus).

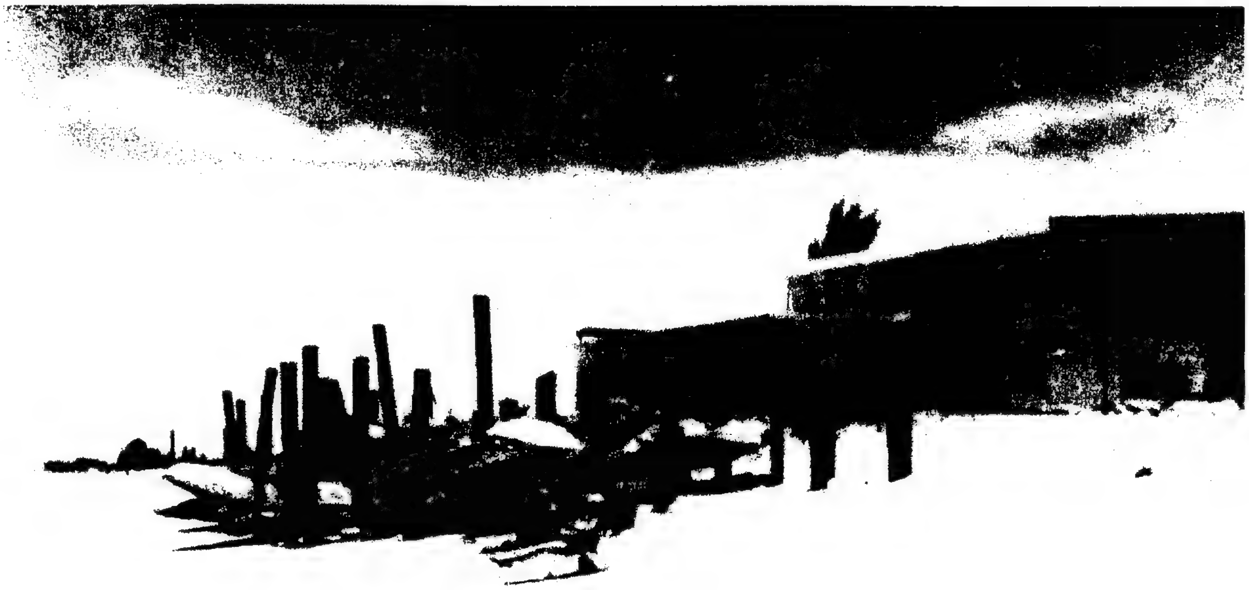

Figure D-6: Applegate property, August 1971. Presence of pilings and concrete rubble indicates this particular house was vulnerable to wave impacts soon after its construction, circa 1960 (source: USACE, Jacksonville District).

Figure D-7: Uncontrolled aerial photograph of Applegate property, October 19, 1972. Downdrift erosion impacts are noticeable just south of the concrete rubble (source: USACE Jacksonville District).

Figure D-8: South side of Applegate property between February 1973 and November 1974 (source: USACE, Jacksonville District).

Figure D-9: Uncontrolled aerial photograph of Applegate property on April 21, 1977; after the USACE 1974/75 beach fill. Concrete rubble seaward of the dwelling was not removed, but buried by the fill (source: USACE, Jacksonville District).

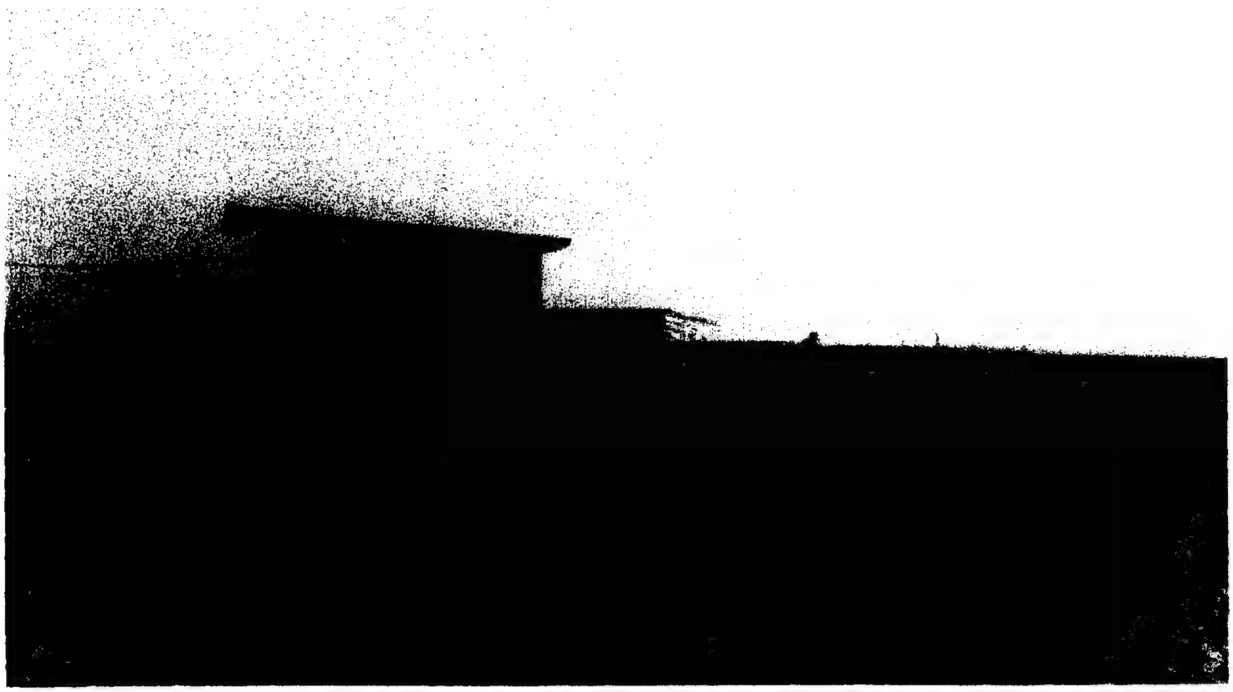

Figure D-10: Viewing north at Applegate property photographed after the USACE 1974/75 beach fill (source: USACE, Jacksonville District).

Figure D-11: Applegate property on May 9, 1996, showing location of rubble mound and structure relative to natural beach features and other structures along the coast (source: N. C. Kraus).

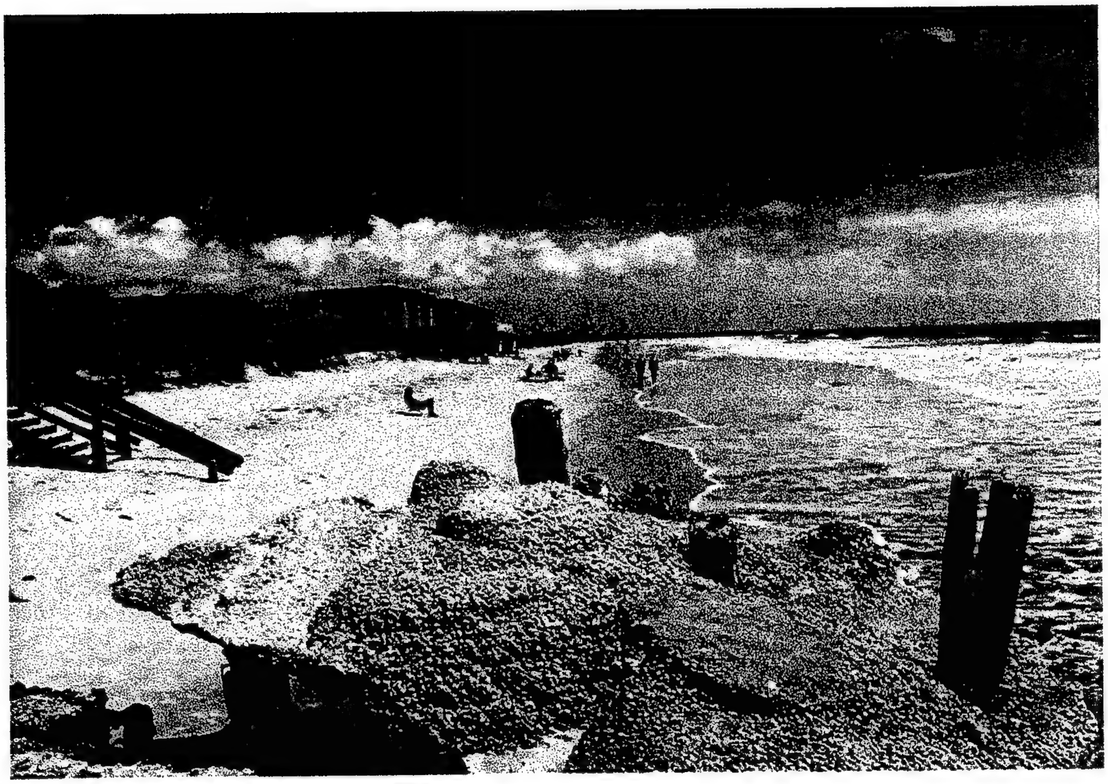

Figure D-12: View looking north from Applegate residence, May 9, 1996 (source: N. C. Kraus).

Figure D-13: View looking south from Applegate residence, May 9, 1996 (source: N. C. Kraus).

Figure D-14: Applegate property, November 21, 1996. Winter beach condition has uncovered more rubble and debris seaward of the house. Rusted vehicle parts can be seen in the foreground (source: N. C. Kraus).

Figure D-15: Southern property boundary of Applegate residence, November 21, 1996, showing downdrift impacts of rubble mound seaward of the structure (source: N. C. Kraus).

Figure D-16: Northern view from Applegate's property, November 21, 1996, showing the narrow beach associated with a typical winter beach profile (source: N. C. Kraus) .

Figure D-17: Applegate property, February 20, 1997 (source: N. C. Kraus).

Figure D-18: Dune face directly north of Applegate property, February 20, 1997, indicating storm erosion (source: N. C. Kraus).

Figure D-19: View north from Applegate property, February 20, 1997 (source: N. C. Kraus).

Figure D-20: Noro and Co. property, May 9, 1996. Note the old stone revetment, deteriorated wooden bulkhead, and the sandbags along the seaward side of the property under the wooden boardwalk (source: N. C. Kraus).

Figure D-21: Noro and Co. property, May 9, 1996, showing the deteriorated wooden bulkhead and geotextile sandbags, as well as storm-induced erosion to the dune face (source: N. C. Kraus).

Figure D-22: View north from Noro and Co. property, May 9, 1996, showing storm damage to the dunes and the remains of attempts to protect upland properties (source: N. C. Kraus).

Figure D-23: Noro and Co. property, November 21, 1996, showing deteriorated wooden bulkhead, geotextile sandbags, and other remains of storm-protection structures (source: N. C. Kraus).

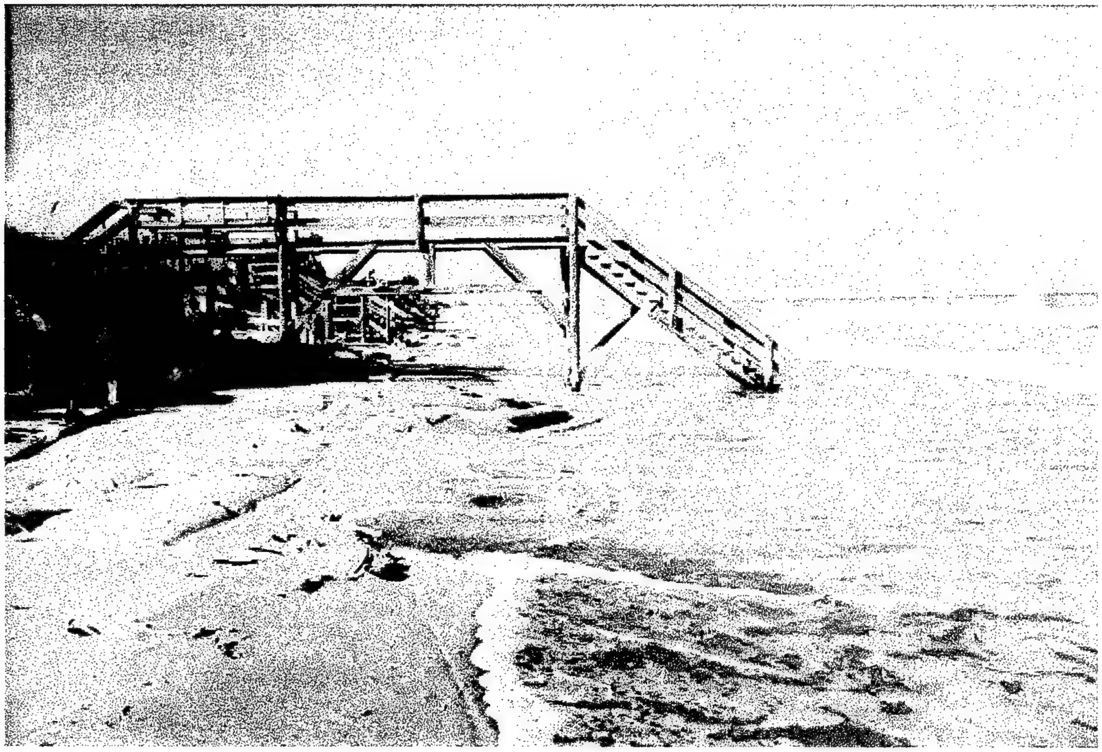

Figure D-24: View north of the boardwalk at Noro and Co. property, November 21, 1996, showing the narrow beach associated with a typical winter profile (source: N. C. Kraus).

Figure D-25: View north of Noro and Co. property, November 21, 1996, showing storm damages to northern neighboring properties (source: N. C. Kraus).

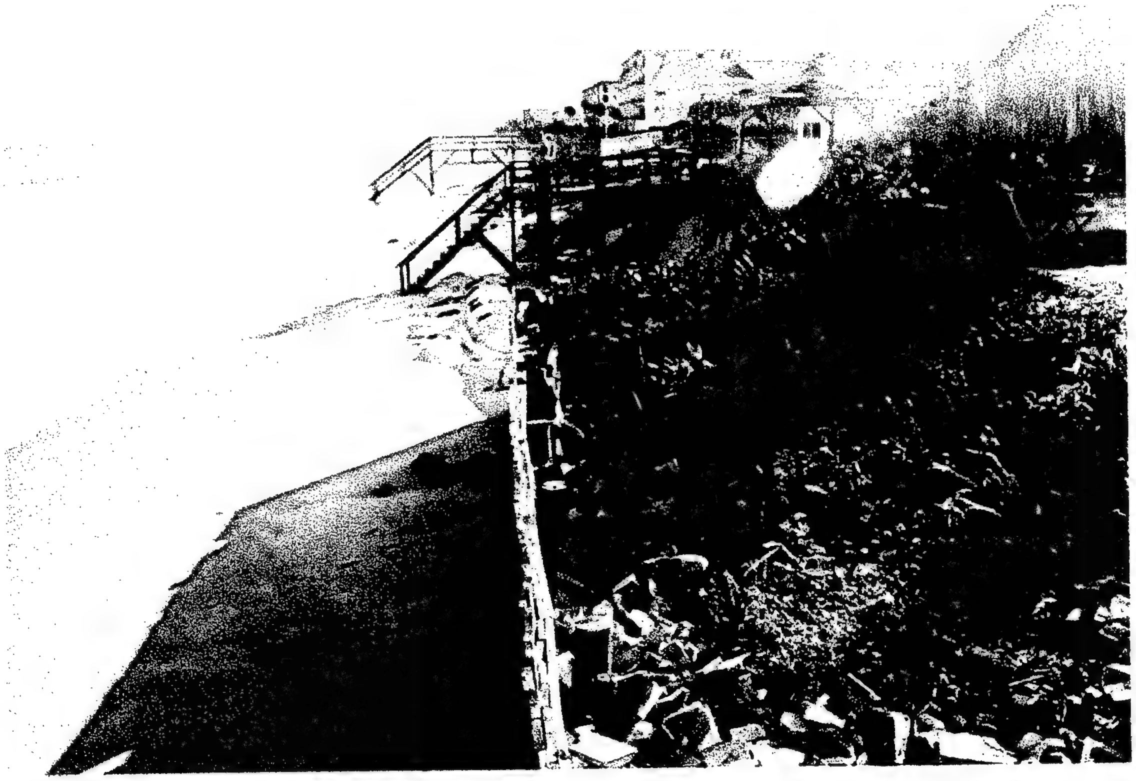

Figure D-26: View south towards Noro property showing the eroded dunes on one property and the creative armoring structures on the neighboring property to the north (source: N. C. Kraus).

Figure D-27: View south from Noro and Co. property showing a wider beach, November 21, 1996 (source: N. C. Kraus).

Figure D-28: Noro and Co. property, February 20, 1997. The remains of the wooden bulkhead are visible just seaward of the wooden deck (source: N. C. Kraus).

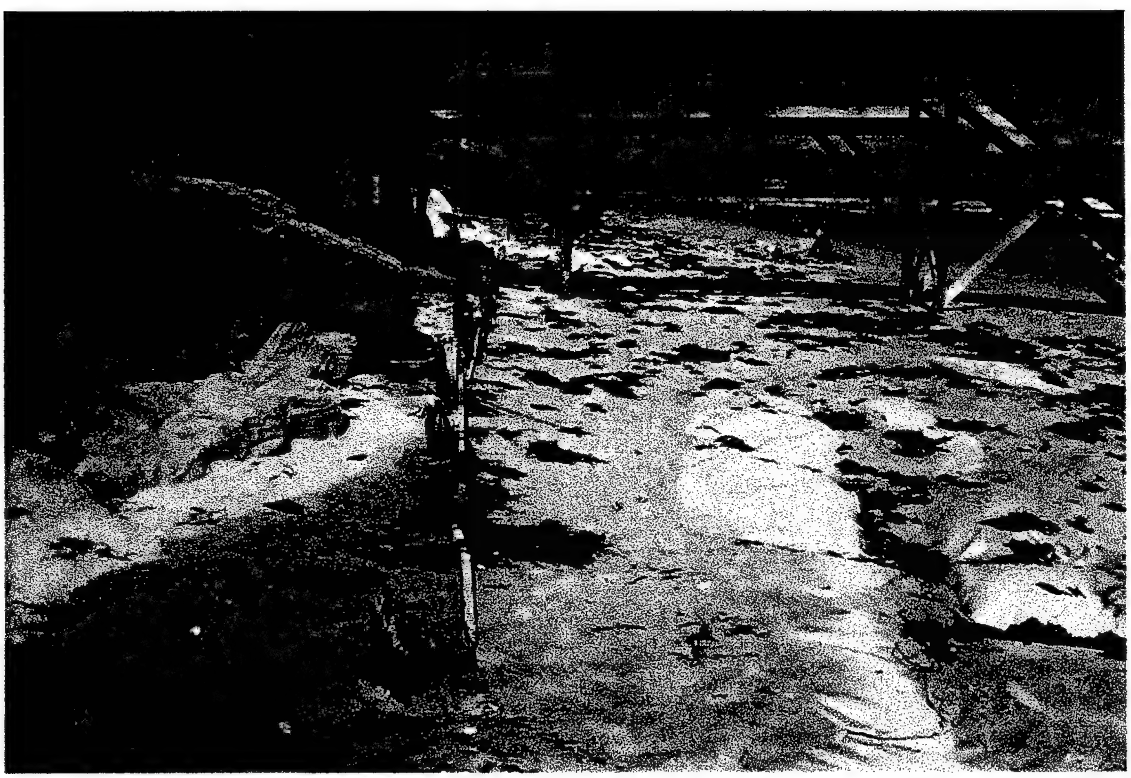

Figure D-29: View north of Noro and Co. property showing the remains of the wooden bulkhead and rock revetment, February 20, 1997(source: N. C. Kraus).

APPENDIX E. Water Levels and Waves

This appendix contains time series of the water levels and waves of the three storms selected to simulate storm-induced beach erosion at the properties of the two test plaintiffs and the extreme water levels measured at the Fernandina and Mayport stations. The calculations are described in Section 3.4 of the main text.

E.1. Storms

The wave data were taken from the Wave Information Study (WIS) Atlantic Hindcast (Hubertz et al. 1993), Station 18, which is located in 22-m (72.2-ft) depth seaward of the Cape Canaveral Shoal. The significant wave height and corresponding peak period at this depth are shown in the plots. Hourly water-level data as provided by National Ocean Service (NOS) and hindcast wave data at 3-hr intervals comprised the oceanic forcing for the dune erosion modeling. Prior to modeling of dune erosion, the wave data time series at the 22-m depth were transformed to the 10-m (33-ft) depth, corresponding to the nominal depth at the seaward ends of the available profile survey data, to account for directional wave spreading and energy losses.

Plots of water level given in this report are referenced to mean tide level (MTL), whereas, in principle, water-level data input to the SBEACH model should be referenced to the National Geodetic Vertical Datum (NGVD). This suggests that some adjustment of the water-level data would be required to convert those elevations to the NGVD datum. Water-level data sets obtained from NOS are referenced to the gauge-specific MTL elevation. The relationship between MTL datum and NGVD datum is not fixed, but varies according to the location of the site in question. For the historic tide gauge at Port Canaveral, NOS has estimated that MTL is 0.19 ft higher than NGVD, as illustrated in Figure 2-7. In comparison, estimated differences between MTL and NGVD at Fernandina, Mayport, and St. Augustine are 0.28, 0.31, and 0.17 ft, respectively; therefore, the differences in conversion values for all four sites was relatively small (within about 0.1 ft). It should also be noted that there are some inherent uncertainties between reference datums, such as the fact that they do not include contributions from relative sea-level rise between the tidal datum epoch (1960-1978) used in their calculation and the present time. For these reasons, it was assumed that the MTL elevations at the tide gauges listed in Table 3-4 are equivalent to the NGVD elevation at Brevard County. Therefore, no MTL-to-NGVD conversion was required for the water-level data input to SBEACH.

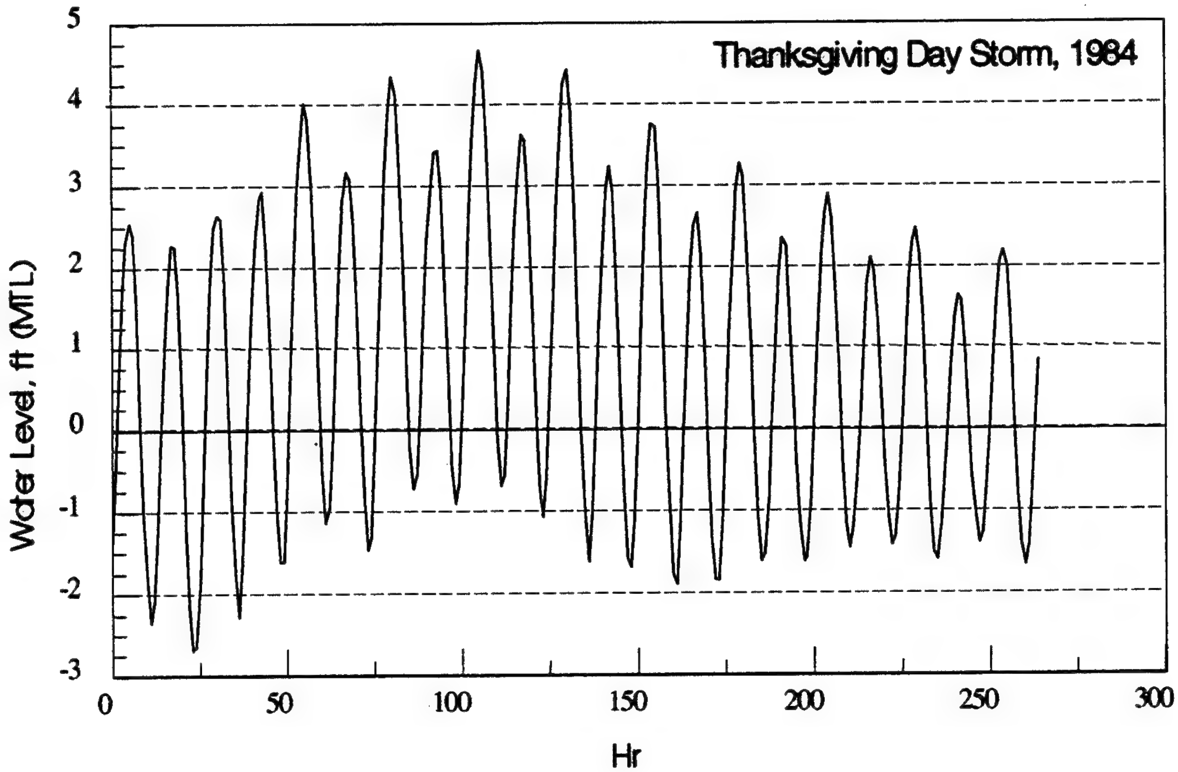

Figure E-1: Thanksgiving Day northeaster, 1984 water level, starting 00 hr 841119.

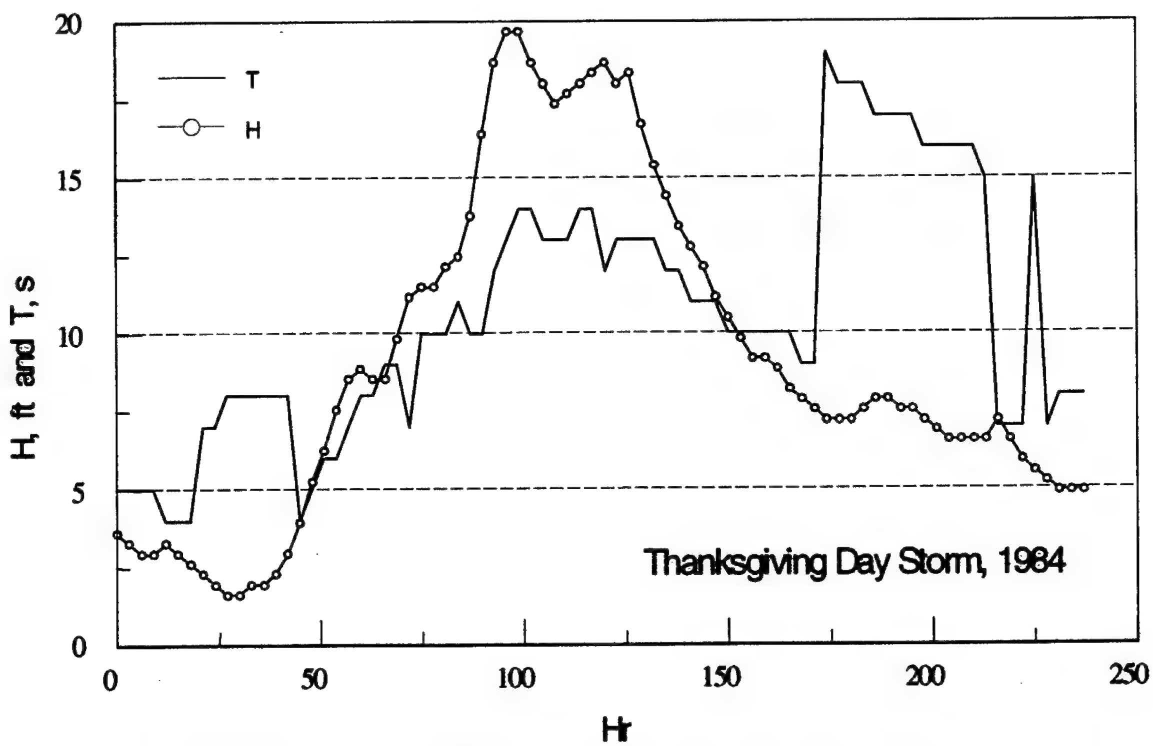

Figure E-2: Thanksgiving Day northeaster, 1984 wave height and period, starting 00 hr 841119.

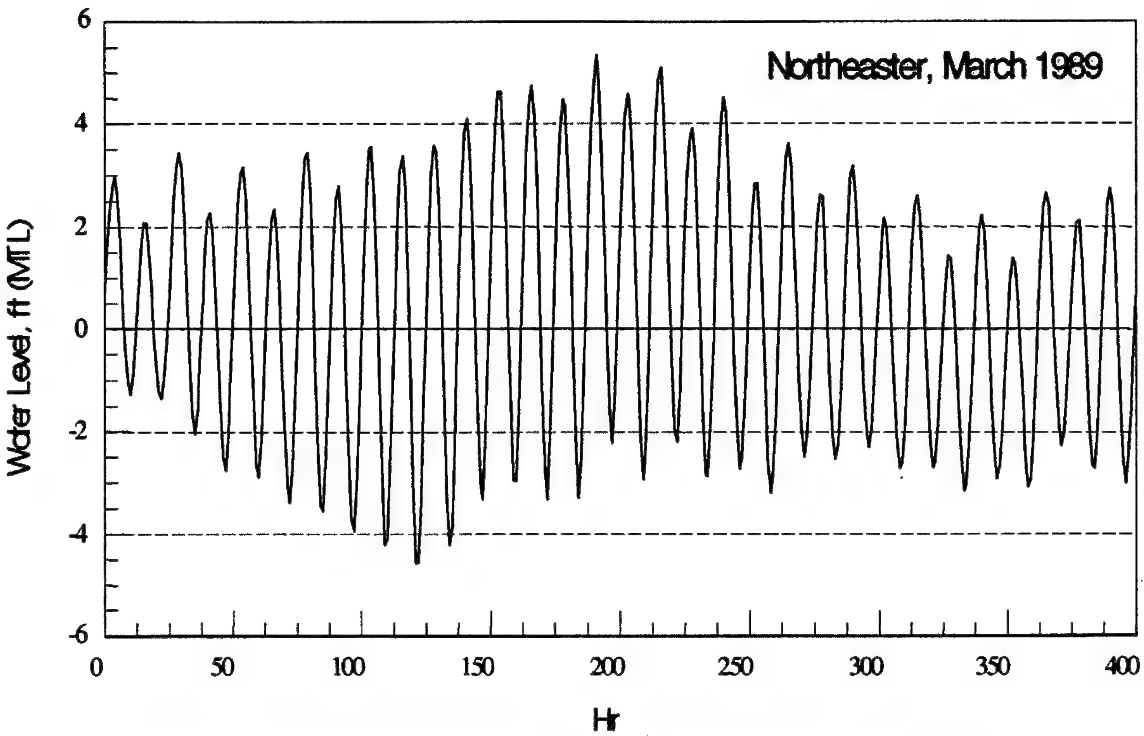

Figure E-3: Northeaster of March 1989 water level, starting 00 hr 890301.

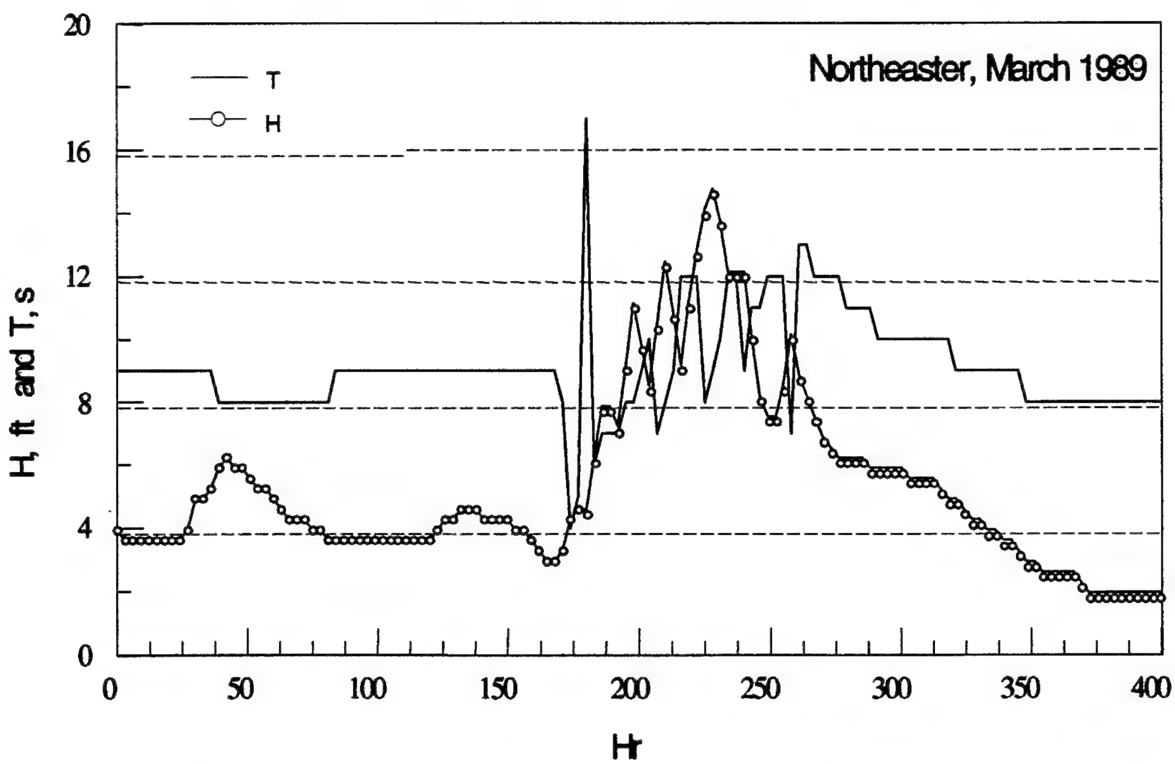

Figure E-4: Northeaster of March 1989 wave height and period, starting 00 hr 890301.

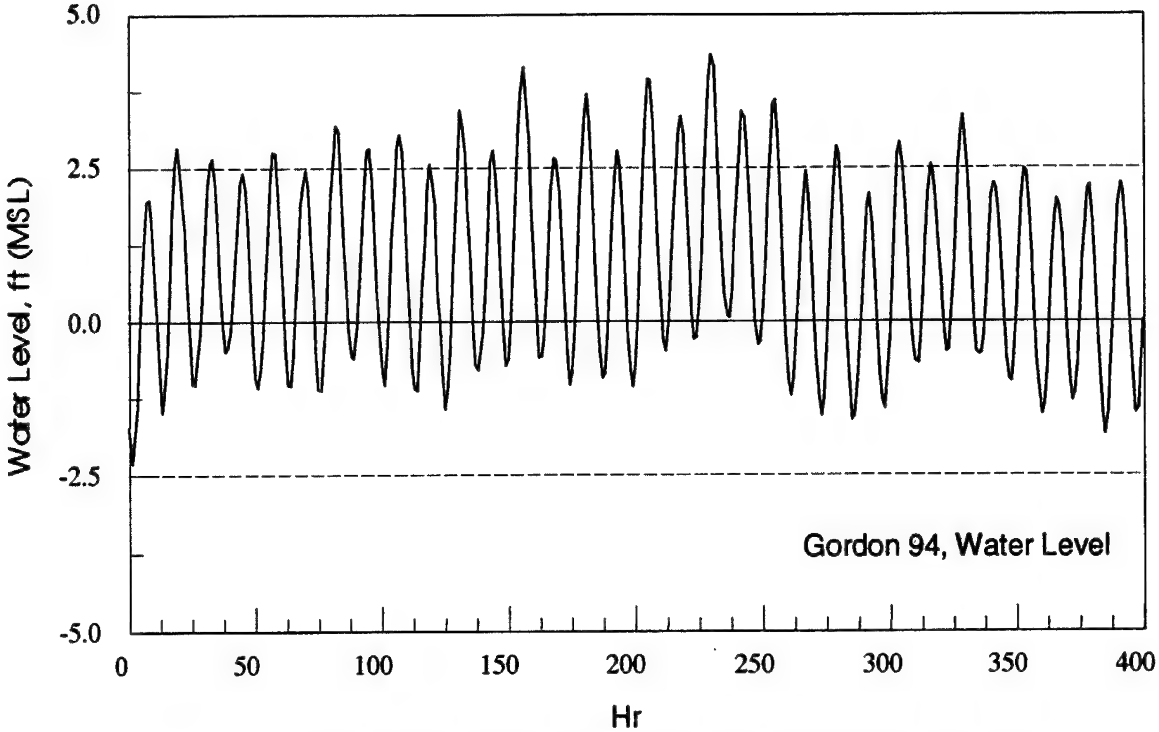

Figure E-5: Tropical Storm Gordon, 1989 water level, starting 00 hr 941110.

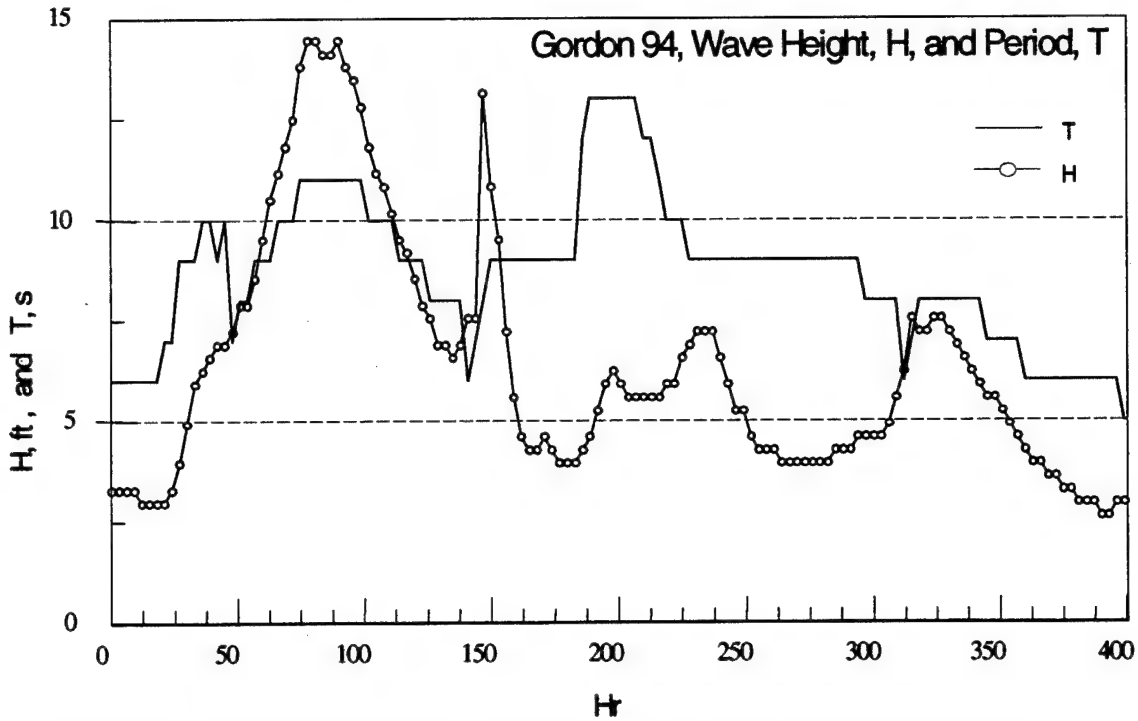

Figure E-6: Tropical Storm Gordon, 1994 wave height and period, starting 00 hr 941110.

E.2. Fernandina and Mayport Extreme Water Levels

This section summarizes an analysis of extreme water levels at the Fenandina Beach, Florida, and Mayport, Florida, tide gauges operated by NOS (NOS Tide Stations 872 0030 and 872 0220, respectively). These are the closest long-term or primary tide stations to the Brevard County beaches that provide records approximating the ocean water level at the project site. The Fernandina Station is located in Cumberland Sound, St. Mary's Entrance, on the Florida-Georgia border, 169 miles north of Canaveral Harbor. The Mayport Station is located in St. Johns River, in Mayport (near Jacksonville), and is located about 145 miles north of Canaveral Harbor.

The plates compiled below contain the elevations and corresponding duration in hours above MSL of water levels exceeding 4.5 ft for the Fernandina Station and 3.7 ft for the Mayport Stations. The plates run from 1979, the year of Hurricane David, to 1995 for Fernandina and to 1985 for Mayport (the end of the continuous record). Hourly water-level data were analyzed to arrive at the values. The cutoffs represent extreme water levels that are likely to produce erosion by allowing waves to reach the upper beach and dune. For reference, the half-tide ranges, defined as half of the difference between mean high water and mean low water (the half range represents the average reach of the tide above MTL or mean sea level), are 2.3 ft for Mayport and 3.0 ft for Fernandina.

The plates were examined by reference to the storms compiled in Appendix C and were found to indicate their presence for the years covered. Because storm-induced erosion increases with increase in water level and the duration of higher water levels, the plates below give a qualitative indication of storm-induced erosion potential for the given storm and year.

5.2.1. Fernandina

1995		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1995.531	4.84	1
1995.528	5.01	1
1995.449	4.92	1
1995.372	4.85	1
1995.526	4.81	0
1995.523	4.57	0
1995.452	4.73	0
1995.284	4.69	0
1995.214	4.81	0
1995.211	4.73	0
1995.001	4.63	0
TOTAL # of events		**11**

1994		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1994.777	5.28	2
1994.757	5.17	2
1994.998	4.98	1
1994.995	4.93	1
1994.766	4.78	1
1994.763	4.88	1
1994.756	4.69	1
1994.394	4.65	1
1994.391	4.84	1
1994.388	4.89	1
1994.922	4.59	0
1994.919	4.84	0
1994.886	4.54	0
1994.790	4.69	0
1994.780	4.57	0
1994.760	4.71	0
1994.758	4.54	0
1994.309	4.60	0
TOTAL # of events		**18**

1993		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1993.102	5.51	2
1993.952	4.55	1
1993.790	5.01	1
1993.787	4.80	1
1993.268	4.71	1
1993.902	4.59	0
1993.867	4.62	0
1993.864	4.72	0
1993.793	4.76	0
1993.266	4.80	0
1993.263	4.66	0
1993.260	4.62	0
1993.100	4.55	0
1993.029	4.91	0
1993.026	4.75	0
TOTAL # of events		**15**

1992		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1992.734	5.25	2
1992.732	5.49	2
1992.731	5.49	2
1992.020	5.32	2
1992.017	5.29	2
1992.888	4.68	1
1992.812	4.68	1
1992.747	4.92	1
1992.744	4.97	1
1992.741	5.01	1
1992.738	4.79	1
1992.735	5.16	1
1992.023	4.69	1
1992.019	4.69	1
1992.737	4.66	0
1992.730	4.59	0
1992.496	4.53	0
1992.493	4.58	0
1992.449	4.52	0
1992.022	4.69	0
1992.016	4.54	0
TOTAL # of events		**21**

1991		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1991.847	4.72	1
1991.689	4.60	1
1991.528	4.69	1
1991.826	4.79	0
1991.771	4.78	0
1991.768	4.74	0
1991.687	4.81	0
TOTAL # of events		**7**

1990		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1990.842	4.75	1
1990.839	4.93	1
1990.394	5.04	1
1990.391	5.02	1
1990.837	4.72	0
1990.763	4.52	0
1990.397	4.56	0
1990.238	4.56	0
1990.235	4.84	0
TOTAL # of events		**9**

1989		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1989.186	5.39	2
1989.498	4.66	1
1989.495	4.68	1
1989.189	5.14	1
1989.182	4.68	1
1989.059	4.80	1
1989.787	4.70	0
1989.739	4.62	0
1989.716	4.56	0
1989.714	4.54	0
1989.192	4.57	0
1989.188	4.63	0
1989.185	4.52	0
1989.183	4.78	0
TOTAL # of events		**14**

1988		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1988.946	4.71	1
1988.894	4.78	1
1988.744	4.58	1
1988.741	4.59	1
1988.738	5.08	1
1988.897	4.59	0
1988.815	4.54	0
1988.290	4.68	0
TOTAL # of events		**8**

1987		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1987.848	4.75	1
1987.001	4.74	1
TOTAL # of events		**2**

1986		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1986.919	4.80	1
1986.916	5.14	1
1986.913	4.57	1
1986.842	4.86	1
1986.712	4.65	1
1986.474	4.93	1
1986.471	4.95	1
1986.028	4.87	1
1986.993	4.63	0
1986.845	4.56	0
1986.391	4.50	0
1986.318	4.58	0
1986.312	4.55	0
1986.020	4.77	0
TOTAL # of events		**14**

1985		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1985.704	5.08	2
1985.701	5.22	2
1985.339	5.07	2
1985.826	4.89	1
1985.796	4.81	1
1985.793	4.76	1
1985.790	4.63	1
1985.787	4.85	1
1985.784	4.96	1
1985.708	5.02	1
1985.707	5.03	1
1985.705	4.97	1
1985.783	4.55	0
1985.782	4.63	0
1985.737	4.51	0
1985.717	4.51	0
1985.711	4.85	0
1985.709	4.53	0
1985.702	4.55	0
1985.342	4.56	0
TOTAL # of events		**20**

1984		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1984.894	5.87	3
1984.891	5.56	3
1984.897	5.31	2
1984.888	5.19	1
1984.818	5.07	1
1984.815	4.62	1
1984.741	5.30	1
1984.056	4.86	1
1984.053	4.54	1
1984.047	4.55	1
1984.820	4.57	0
1984.654	4.56	0
TOTAL # of events		**12**

1983		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1983.446	5.12	2
1983.160	5.24	2
1983.971	4.83	1
1983.443	5.14	1
1983.441	4.79	1
1983.157	4.82	1
1983.001	4.64	1
1983.853	4.52	0
1983.845	4.50	0
1983.768	4.58	0
1983.520	4.59	0
1983.517	4.63	0
1983.449	4.63	0
1983.438	4.52	0
1983.154	4.67	0
1983.081	4.53	0
1983.078	4.64	0
1983.075	4.58	0
TOTAL # of events		**18**

1982		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1982.998	4.86	1
TOTAL # of events		**1**

1981		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1981.784	5.57	3
1981.870	5.56	2
1981.867	5.99	2
1981.864	5.87	2
1981.861	5.32	2
1981.787	5.37	2
1981.783	5.20	2
1981.351	5.04	2
1981.348	5.06	2
1981.949	4.67	1
1981.943	4.69	1
1981.872	5.08	1
1981.865	4.87	1
1981.782	5.12	1
1981.501	4.67	1
1981.342	4.87	1
1981.339	4.75	1
1981.337	4.61	1
1981.868	4.58	0
1981.863	4.53	0
1981.790	4.83	0
1981.786	4.76	0
1981.780	4.57	0
1981.495	4.59	0
1981.493	4.65	0
1981.345	4.91	0
TOTAL # of events		**26**

1980		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1980.812	5.23	2
1980.974	4.97	1
1980.971	5.16	1
1980.891	4.81	1
1980.811	4.97	1
1980.741	4.98	1
1980.449	4.66	1
1980.446	4.87	1
1980.372	4.92	1
1980.894	4.53	0
1980.889	4.66	0
1980.809	4.64	0
1980.738	4.63	0
1980.649	4.58	0
1980.370	4.64	0
1980.137	4.51	0
1980.134	4.57	0
1980.133	4.52	0
1980.130	4.58	0
1980.050	4.75	0
1980.048	4.63	0
TOTAL # of events		**21**

1979		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1979.675	5.52	3
1979.692	4.89	1
1979.673	4.71	1
1979.526	4.61	1
1979.523	4.93	1
1979.520	4.79	1
1979.452	4.74	1
1979.449	4.95	1
1979.446	5.04	1
1979.695	4.58	0
1979.689	4.58	0
1979.517	4.62	0
1979.455	4.53	0
1979.444	4.69	0
TOTAL # of events		**14**

5.2.2. Mayport

1985		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1985.705	3.89	2
1985.828	3.92	1
1985.826	3.89	1
1985.796	3.86	1
1985.787	3.90	1
1985.784	3.92	1
1985.736	3.77	1
1985.711	3.86	1
1985.708	3.93	1
1985.707	3.84	1
1985.704	3.77	1
1985.701	3.82	1
1985.820	3.63	0
1985.793	3.79	0
1985.790	3.76	0
1985.783	3.63	0
1985.782	3.66	0
1985.709	3.63	0
1985.339	3.61	0
TOTAL # of events		**19**

1984		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1984.897	4.30	2
1984.894	4.54	2
1984.891	4.21	2
1984.817	3.93	2
1984.741	4.17	2
1984.888	3.89	1
1984.815	3.66	0
1984.056	3.63	0
TOTAL # of events		**8**

1983		
YEAR	Max Wtrlvl (MSL)	Duration (HRS)
1983.446	3.88	1
1983.443	3.91	1
1983.160	3.88	1
1983.441	3.67	0
TOTAL # of events		**4**

1982		
Year	Max Wtrlvl (MSL)	Duration (HRS)
TOTAL # of events		**0**

1981		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1981.867	4.67	3
1981.864	4.62	3
1981.872	4.10	2
1981.870	4.40	2
1981.861	4.16	2
1981.787	4.26	2
1981.784	4.39	2
1981.782	4.03	2
1981.865	3.97	1
1981.790	3.87	1
1981.786	3.71	1
1981.783	3.99	1
1981.351	3.79	1
1981.348	3.66	1
1981.868	3.78	0
1981.863	3.71	0
1981.342	3.65	0
TOTAL # of events		**17**

1980		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1980.812	3.93	1
1980.741	3.75	1
1980.372	3.66	1
1980.971	3.72	0
1980.891	3.69	0
1980.888	3.63	0
1980.449	3.62	0
1980.050	3.62	0
TOTAL # of events		**8**

1979		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1979.738	4.47	4
1979.735	4.47	4
1979.674	5.17	4
1979.673	5.07	4
1979.733	4.57	3
1979.731	4.37	3
1979.730	4.47	3
1979.720	4.37	3
1979.697	4.47	3
1979.694	4.77	3
1979.693	4.47	3
1979.692	4.77	3
1979.690	4.67	3
1979.689	4.47	3
1979.747	4.07	2
1979.744	4.07	2
1979.741	4.17	2
1979.740	4.07	2
1979.737	4.17	2
1979.734	4.27	2
1979.724	3.87	2
1979.721	4.17	2
1979.719	4.07	2
1979.714	3.97	2
1979.712	4.07	2
1979.709	3.97	2
1979.700	4.07	2
1979.696	4.37	2
1979.687	4.27	2
1979.686	4.27	2
1979.682	4.17	2
1979.679	4.37	2
1979.670	4.17	2
1979.667	3.97	2
1979.845	3.88	1
1979.728	3.87	1
1979.727	3.97	1
1979.723	4.07	1
1979.717	3.97	1
1979.699	3.97	1
1979.685	4.17	1
1979.683	3.97	1
1979.680	4.07	1

1979		
Year	Max Wtrlvl (MSL)	Duration (HRS)
1979.672	3.97	1
1979.446	3.64	1
1979.842	3.63	0
1979.745	3.67	0
1979.743	3.67	0
1979.726	3.77	0
1979.716	3.77	0
1979.713	3.67	0
1979.710	3.67	0
1979.703	3.67	0
1979.676	3.77	0
1979.523	3.67	0
1979.127	4.22	0
TOTAL # of events		**56**

APPENDIX F. Brevard County Federal Projects and Surveys[35]

This appendix describes the Federal navigation project at Canaveral Harbor, Florida, and the Federal shore-protection project for Brevard County, Florida. Many surveys have been made by the U.S. Army Corps of Engineers (USACE) for the purposes of study, construction, and monitoring of these two projects. These survey data sets have not been accessed in previous studies of Harbor impacts on the adjacent shores of Brevard County. The USACE survey data are analyzed and the results presented in this appendix.

F.1. Canaveral Harbor, Florida, Navigation Project

The River and Harbor Act of March 2, 1945 (Public Law 79-14), authorized a 27-ft-deep entrance channel, jetties, a 27-ft-deep turning basin enclosed by a dike, and an 8-ft-deep barge canal lock. The project is described in House Document 367, 77th Congress, 1st Session, dated October 14, 1941. A location map with project features is shown in Figure F-1.

Harbor Construction. The work began in June 1950. During the first full year of dredging, almost 6 Mcy were moved from the turning basin and the barge and slip canals. The dredged material was constructed into a dike around the turning basin and the Merritt Island causeway. The pilot cut was made in October 1951. The entrance channel was about 90 % complete in March 1952 when dredging was suspended from lack of progress because of rapid shoaling of the channel. To stabilize the land points and reduce shoaling, construction of jetties and bank revetments were undertaken on an emergency basis in June 1953. A section of the south jetty about 813 ft in length and 445 ft of bank revetment (along the south bank of the land cut beginning at the shore end of the jetty) was constructed between June 2, 1953, and November 10, 1953. The revetment was added because erosion was occurring at the south shore adjacent to the channel. Between December 1953 and June 1954, the north jetty was constructed 1,150 ft long to the 12-ft contour, and a 300-ft-long revetment was placed along the north shore extending south from the landward end of the north jetty. By September 3, 1954, a 300-ft extension to the south jetty was constructed, and the south-shore revetment was extended landward an additional 1,200 ft.

The ocean entrance channel and turning basin were enlarged and deepened with military funds between November 1956 and May 1957 to 33 ft in the turning basin, 34 ft in the entrance channel through the land cut, and 36 ft in the approach channel. In 1958, the north revetment was extended 600 ft westward, and the south revetment was extended westward to the Port Authority wharf. In 1961, the channel was further deepened to 37 ft with military funds.

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[35] This appendix was prepared by Mr. David V. Schmidt, P.E., Supervisory Civil Engineer, USACE Jacksonville District, Jacksonville, Florida.

Between April 1974 and March 1975, the Harbor entrance channel was deepened from 37 to 44 ft and a new turning basin and access channel constructed to a depth of 41 ft for the Trident Missile Defense System. Approximately 4 Mcy were removed from the entrance channel, and 9 Mcy were removed from the turning basin and access channel. Local interests completed the deepening of the west access channel and west turning basin from the authorized 31 to 35 ft in May 1987.

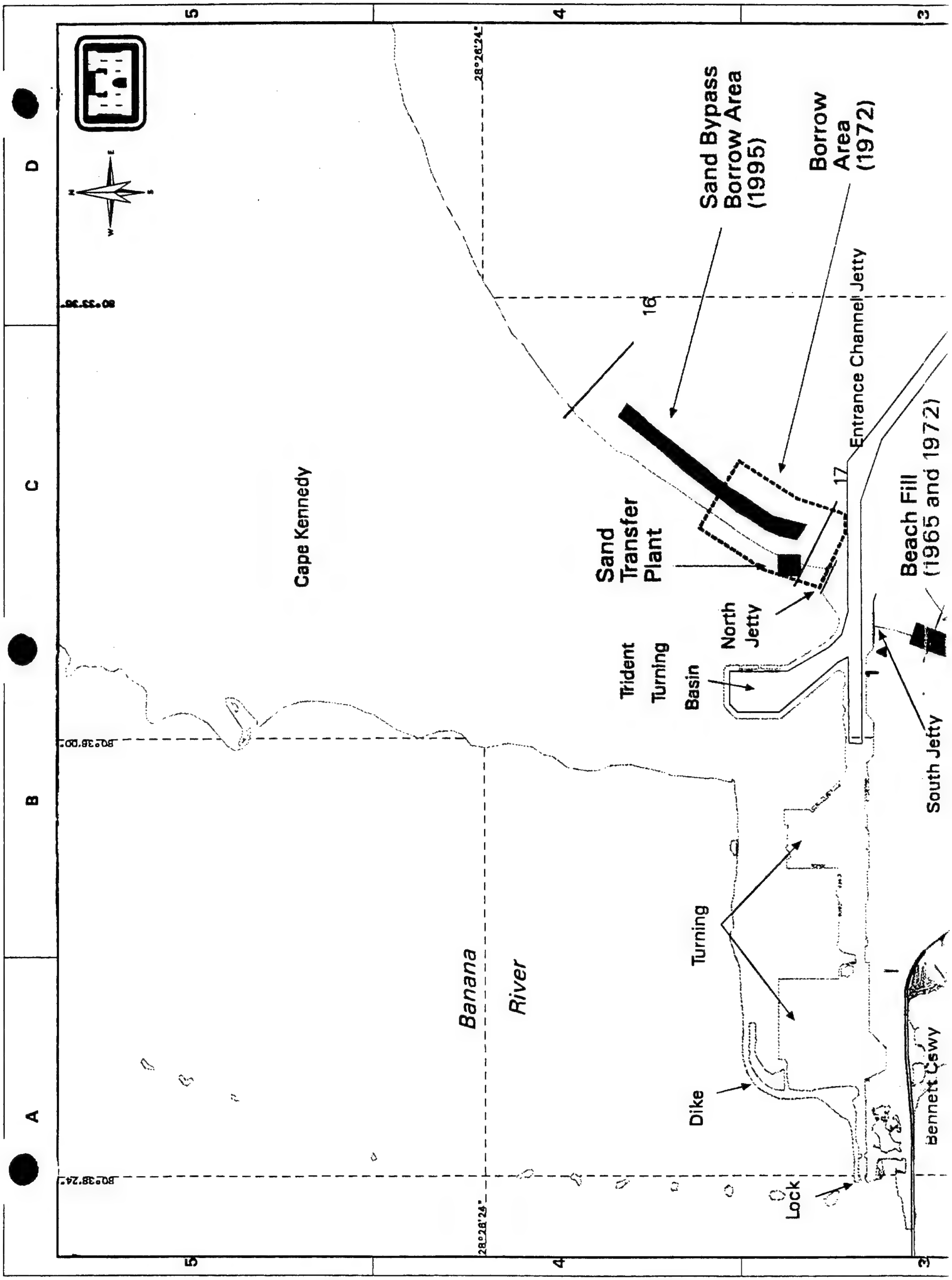
Deepening of the Harbor entrance channel from 37 to 41 ft, the inner channel from 36 to 40 ft and widening it to 400 ft, the middle turning basin from 35 to 39 ft to provide for a 1,200-ft-diameter turning area, and the north channel branch from 35 to 39 ft with a width of 350 ft, was started in August 1993 and completed in October 1994. Construction of the authorized fishing walkway, located on the south jetty, was coordinated with the jetty extension and sand-tightening project. The south jetty sand-tightening work was completed in September 1995. The first sand bypassing was completed in September 1995.

F.1.1. Harbor Project Modifications

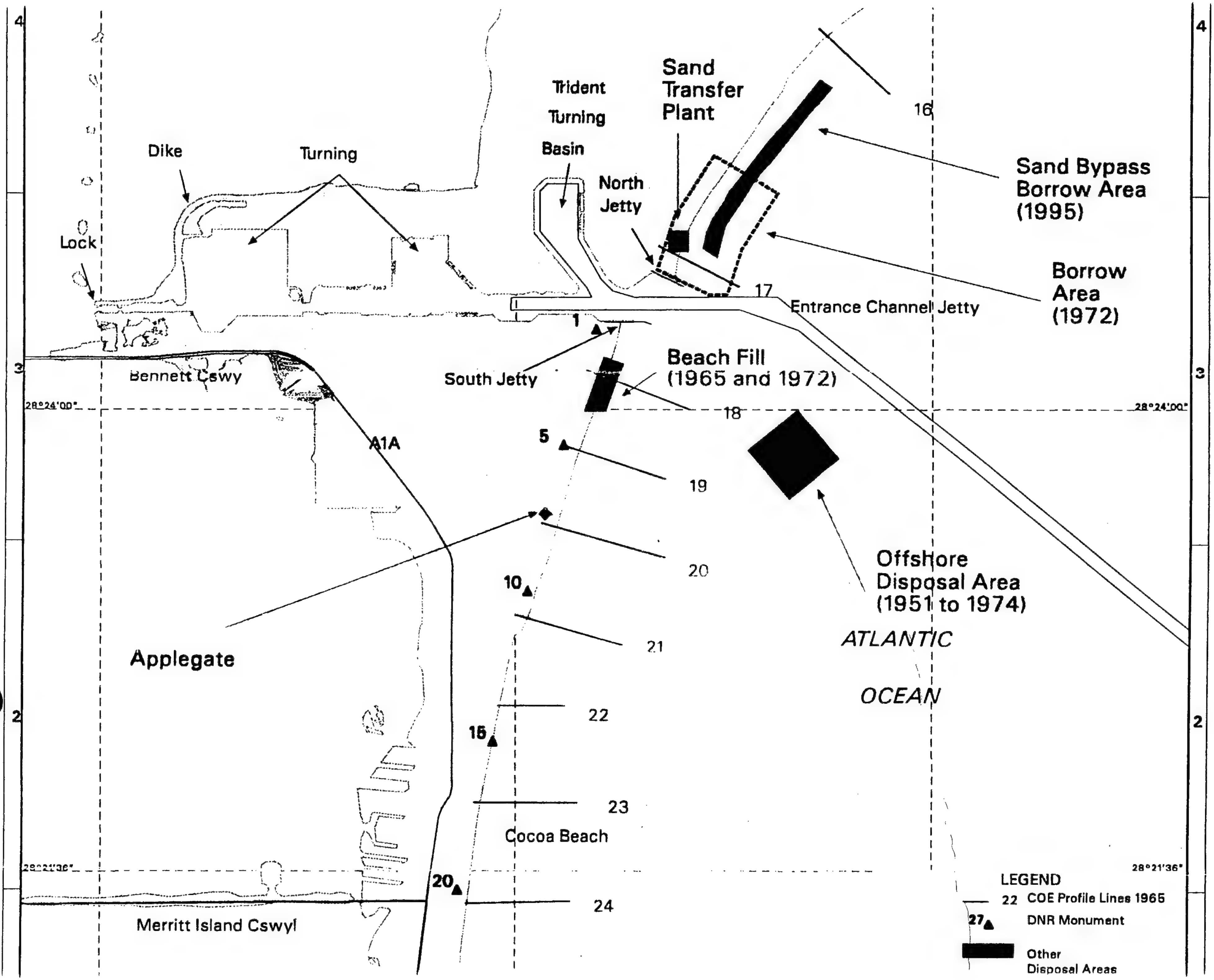
1951 Project Review Study. The Senate Public Works Committee by resolution adopted April 26, 1951, directed the USACE to review the report of the Chief of Engineers on Canaveral Harbor (House Document 367/77/1) to determine if the project should be modified. The purpose of the study was to consider the advisability of maintaining the enlarged and deepened harbor with civil works funds, deepening and enlarging the existing barge channel, enlarging the dike-enclosed harbor area, modifying the requirements of local cooperation, and proceeding with construction of a barge lock. The USACE Jacksonville District Engineer's feasibility report in response to the Congressional resolution is dated October 30, 1961. The report of the Board of Engineers for Rivers and Harbors is dated March 23, 1962. The report of the Chief of Engineers is dated July 6, 1962. The Secretary of the Army transmitted the study results to Congress on September 24, 1962. The project was modified as follows.

1962 Sand Transfer Plant Authority. The River and Harbor Act of October 23, 1962 (Public Law 87-874), authorized maintenance of improved channel and turning basin. It also authorized enlarging a barge channel and lock, relocating the dike, constructing a channel and turning basin west of 35-ft turning basin, and constructing and operating of a sand-transfer plant. Project modifications are described in Senate Document 140, 87th Congress, 2nd Session dated September 24, 1962. The purpose of the sand-transfer plant, in combination with conventional dredging, was to maintain the navigation project entrance channel.

1990 Project Deepening Study. Title I, Section 101(7) of the 1992 Water Resources Development Act authorized modifications to the Canaveral Harbor, Florida, project. The authorization provides for increasing the depth of the entrance channel from 37 to 41 ft and

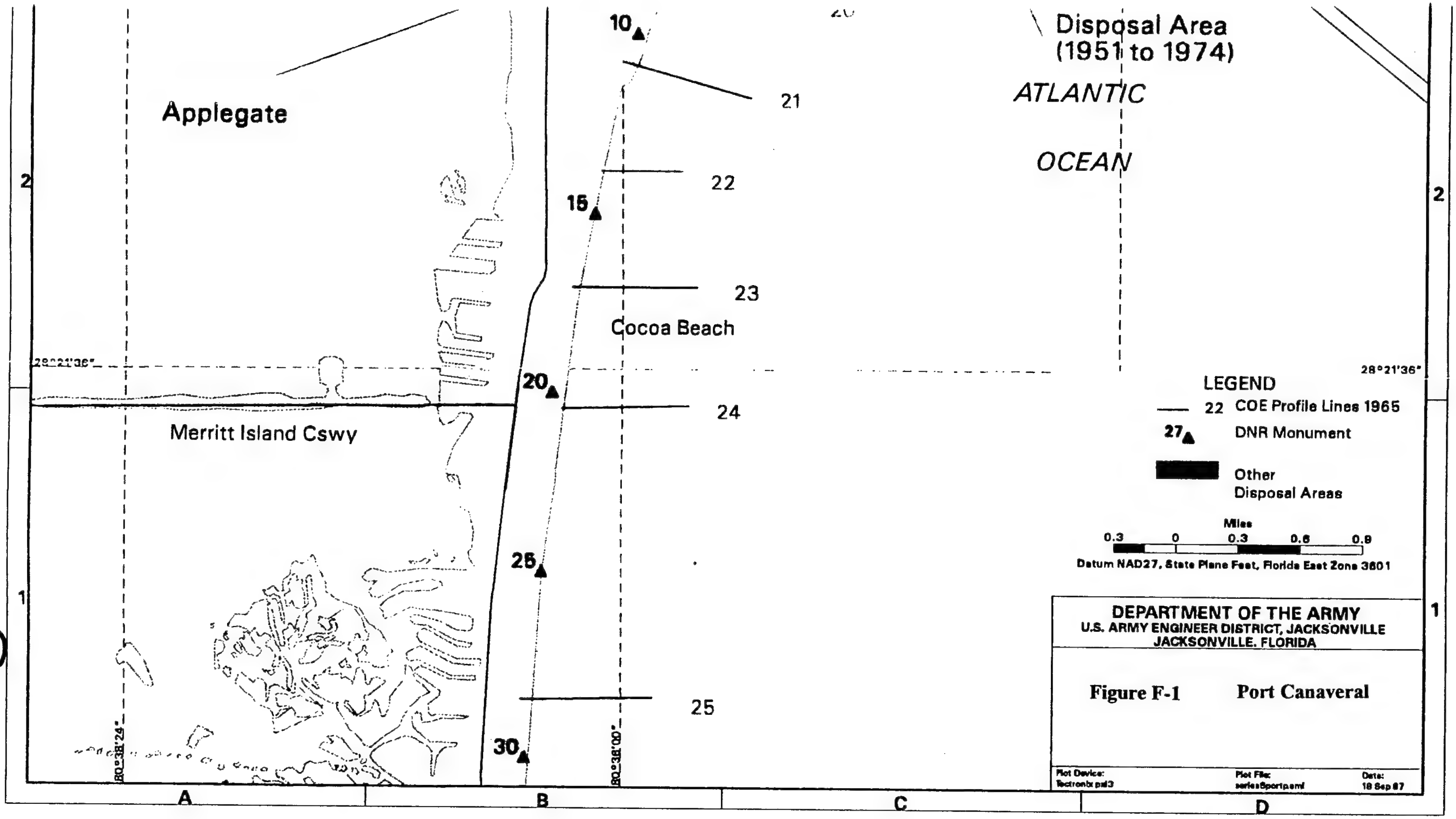

Sand Bypass Borrow Area (1995)
Borrow Area (1972)
Entrance Channel Jetty
16
17
Sand Transfer Plant
North Jetty
Beach Fill (1965 and 1972)
Trident Turning Basin
South Jetty
Cape Kennedy
Banana River
Turning
Dike
Lock
Bennett Cswy
28°28'24"
80°33'36"
80°36'00"
80°38'24"
A
B
C
D
3
4
5

①



Sand Transfer Plant
Trident Turning Basin
North Jetty
Dike
Turning
Lock
16
17
18
19
20
21
22
23
24
Sand Bypass Borrow Area (1995)
Borrow Area (1972)
Entrance Channel Jetty
1
Beach Fill (1965 and 1972)
South Jetty
Bennett Cswy
28°24'00"
A1A
5
10
15
20
Applegate
Offshore Disposal Area (1951 to 1974)
ATLANTIC
OCEAN
Cocoa Beach
28°21'36"
Merritt Island Cswyl
LEGEND
22 COE Profile Lines 1965
27 DNR Monument
Other Disposal Areas

(2)


Disposal Area
(1951 to 1974)
ATLANTIC
OCEAN
Applegate
Cocoa Beach
Merritt Island Cswy
10
15
20
25
30
21
22
23
24
25
28°21'36"
28°21'36"
80°38'24"
80°36'00"
2
1
A
B
C
D
LEGEND
22 COE Profile Lines 1965
27 DNR Monument
Other
Disposal Areas
Miles
0.3 0 0.3 0.6 0.9
Datum NAD27, State Plane Feet, Florida East Zone 3601
DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
JACKSONVILLE, FLORIDA
Figure F-1
Port Canaveral
Plot Device:
Tectronix psl3
Plot File:
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Date:
18 Sep 97

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deepening of the inner channel from 36 to 40 ft and widening it to 400 ft. The middle turning basin would be deepened from 35 to 39 ft to provide for a 1,200-ft-diameter turning area. The north channel branch would be deepened from 35 to 39 ft with a width of 350 ft. A description of the project is contained in the report of the Chief of Engineers dated July 24, 1991, as modified by the letter of the Secretary of the Army dated October 10, 1991. Reference House Document 102-156, 102nd Congress, 1st Session, dated October 21, 1991, and the District feasibility report on deepening dated August 1990.

1993 Sand-Bypass Modification. General Re-evaluation Report, Sand-Bypass System, Canaveral Harbor, Florida, December 1992, Revised November 1993. The project modified the sand-bypass feature from a fixed sand-transfer plant at the north jetty to hydraulic dredging from a borrow site north of the jetty to the beach south of the inlet. The plan is to bypass 636,000 cy of sand every 6 years (106,000 cy/year). Another feature of the modified bypass system was to lengthen and sand-tighten the south jetty. The project modifications were approved by the Chief of Engineers in 1994.

F.1.2. Canaveral Harbor Dredged Material

Volumes of dredged material removed from Canaveral Harbor are listed in Table F-1. Prior to 1974, dredged material was placed either in the ocean disposal site (Figure F-1) or stockpiled in upland disposal areas, except for 120,000 cy in 1965 and 200,000 cy in 1972. Since 1974, a combination of upland, offshore, beach, and nearshore disposal locations have been used (Figure F-2).

Table F-1. Canaveral Harbor, Florida. Summary of dredging volumes (cy).

Location Placed	New Work Only	Pre-Trident 1951 to Apr-74	Post-Trident Apr-74 to 1997	Total
Upland	8,848,971	499,746	10,886,142	**11,385,888**
1952 to 1974 Offshore	3,317,098	13,234,838	0	**13,234,838**
1974 to 1997 ODMDS	7,361,388	0	20,999,196	**20,999,196**
Beach	2,966,963	320,000	3,598,605	**3,918,605**
Nearshore	0	0	893,560	**893,560**
TOTALS	**22,494,420**	**14,056,461**	**36,379,426**	**50,432,087**

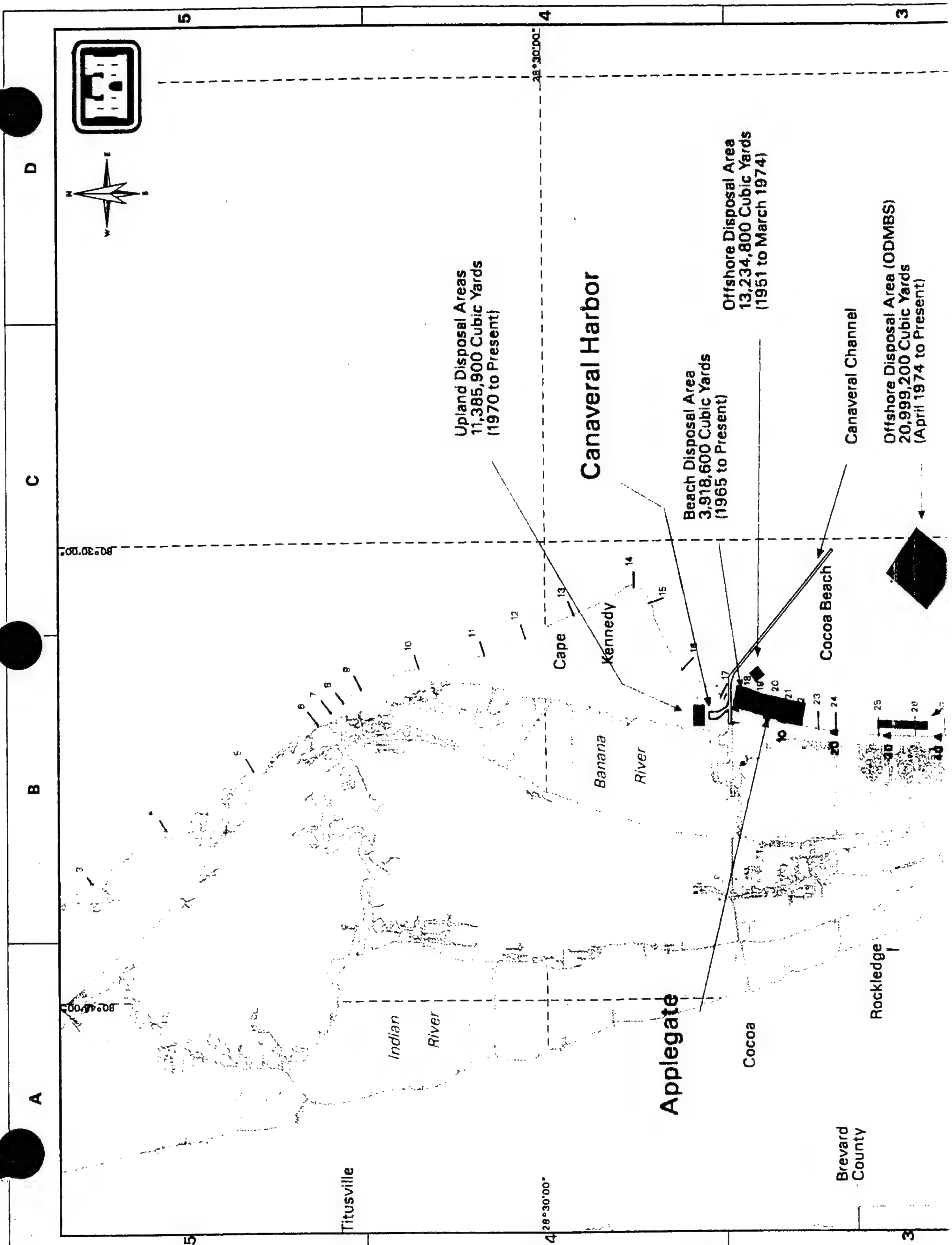
Aproximately 50.2 Mcy of dredged material have been removed from Canaveral Harbor, as shown in Table F-1. Approximately 22 Mcy were removed as a result of new work (initial construction) and 28.2 Mcy were removed from maintenance of the Harbor. Prior to April 1974, approximately 13.2 Mcy of dredged material from Canaveral Harbor was placed in the offshore disposal site shown on Figure F-1. Another 499,700 cy were placed in upland disposal areas. Approximately 120,000 and 200,000 cy were placed in the beach disposal area shown on Figure F-1 in 1965 and 1972, respectively. Since April 1974, upland, offshore, beach, and nearshore (0.9 Mcy) disposal locations have been used. The total dredged-material disposal placed in these areas is shown on Figure F-2. In April 1974, the offshore disposal site was changed to an area further offshore. The area of this "interim" offshore disposal area was 3 square nautical miles. The interim offshore disposal area was increased in size to 4 square nautical miles and designated as an Offshore Dredged-Material Disposal Site (ODMDS) by the Environmental Protection Agency in 1990. A total of 21 Mcy have been placed in the ODMDS for Canaveral Harbor since April 1974.

F.2. Brevard County, Florida, Shore-Protection Project

The 1968 Rivers and Harbors Act (Public Law 90-483) authorized a beach-erosion control project for Brevard County, Florida. The project is described in House Document 352, 90th Congress, 2nd Session dated July 8, 1968. Five areas were identified as having erosion problems, two north of Canaveral Harbor and three south. These areas are shown in Figure F-3. The lengths of the problem areas are, in order from north to south, 4.9 miles at Kennedy Space Center, 4 miles at Cape Kennedy Air Force Station (AFS), 2.8 miles at the city of Cape Canaveral, 2.3 miles at Patrick AFB, and 2 miles at Indialantic and Melbourne Beach. Federal Civil Works participation was authorized for the City of Cape Canaveral and at Indialantic/Melbourne Beach. The three remaining areas are Federal property, and the Federal agencies involved would be responsible for constructing the projects recommended. Descriptions of the recommended project areas follows:

Kennedy Space Center. Restore 26,000 ft (4.9 miles) of beach at Kennedy Space Center without Federal (Civil Works) participation. Federal agencies owning property involved would be responsible for their own justification and funding for project construction. Volume needed for initial restoration was 2.5 Mcy. Approximately 195,000 cy would be needed annually for periodic nourishment (7.5 cy/ft).

Cape Kennedy AFS. Restore 21,200 ft (4.0 miles) of beach at Cape Kennedy AFS without Federal (Civil Works) participation. Federal agencies owning property involved would be responsible for their own justification and funding for project construction. Volume needed for initial restoration was 2.0 Mcy. Approximately 162,000 cy would be needed annually for periodic nourishment (7.6 cy/ft).



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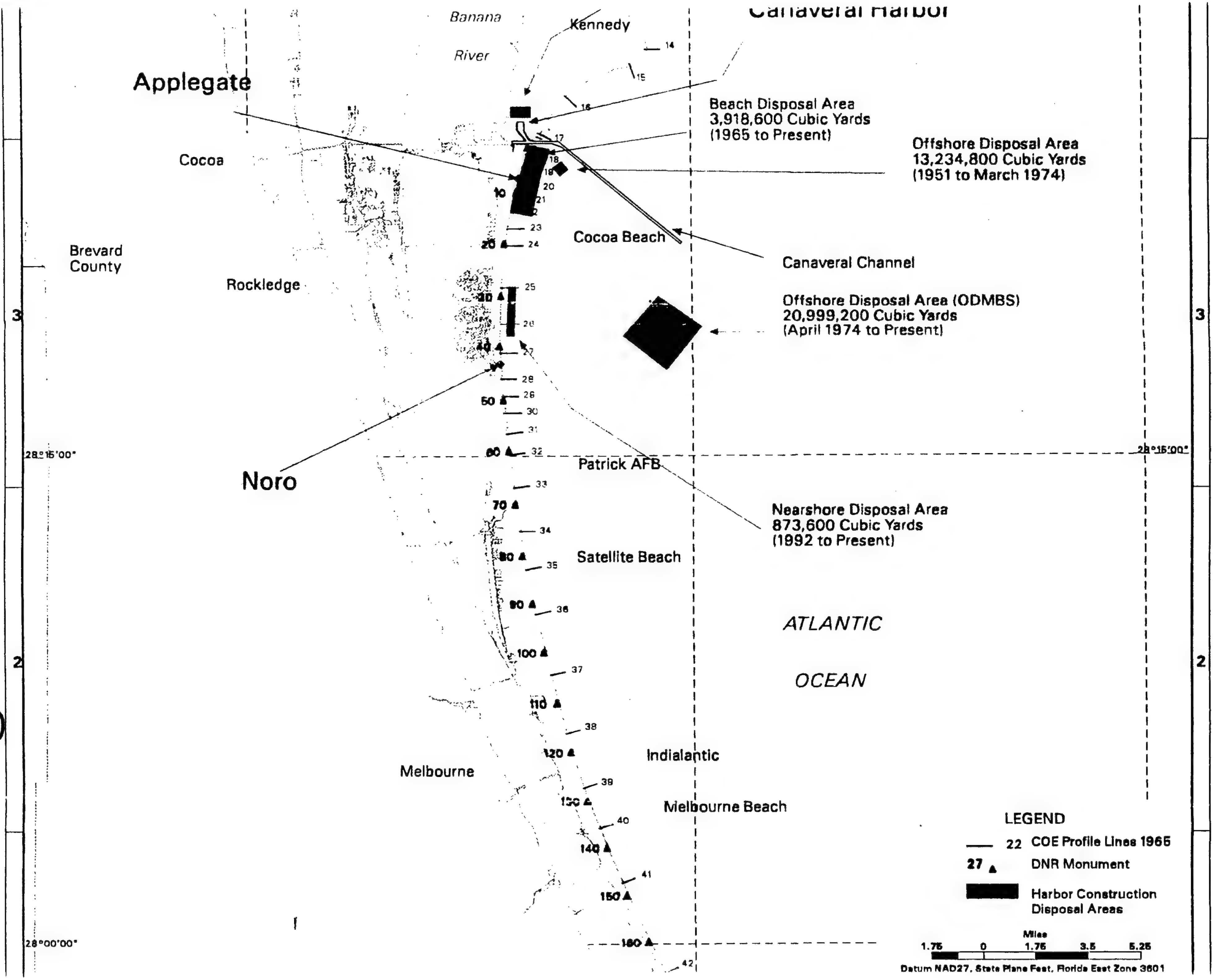

Canaveral Harbor
Banana
River
Kennedy
Applegate
Noro
Cocoa
Brevard
County
Rockledge
Cocoa Beach
Patrick AFB
Satellite Beach
Indialantic
Melbourne
Melbourne Beach
ATLANTIC
OCEAN
Beach Disposal Area
3,918,600 Cubic Yards
(1965 to Present)
Offshore Disposal Area
13,234,800 Cubic Yards
(1951 to March 1974)
Canaveral Channel
Offshore Disposal Area (ODMBS)
20,999,200 Cubic Yards
(April 1974 to Present)
Nearshore Disposal Area
873,600 Cubic Yards
(1992 to Present)
28°15'00"
28°00'00"
LEGEND
22 COE Profile Lines 1965
27 DNR Monument
Harbor Construction
Disposal Areas
Miles
1.75 0 1.75 3.5 5.25
Datum NAD27, State Plane Feet, Florida East Zone 3601

2

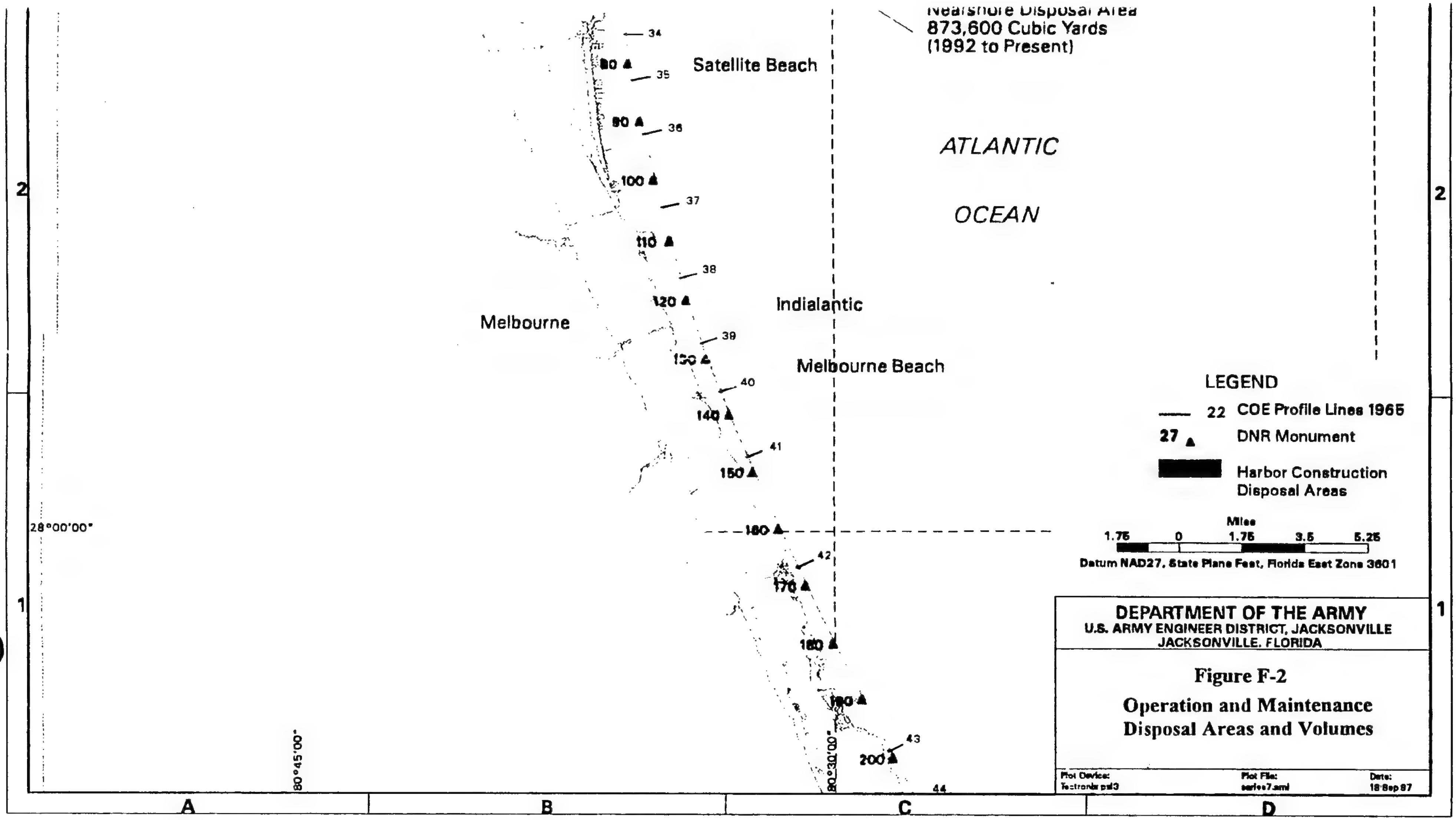
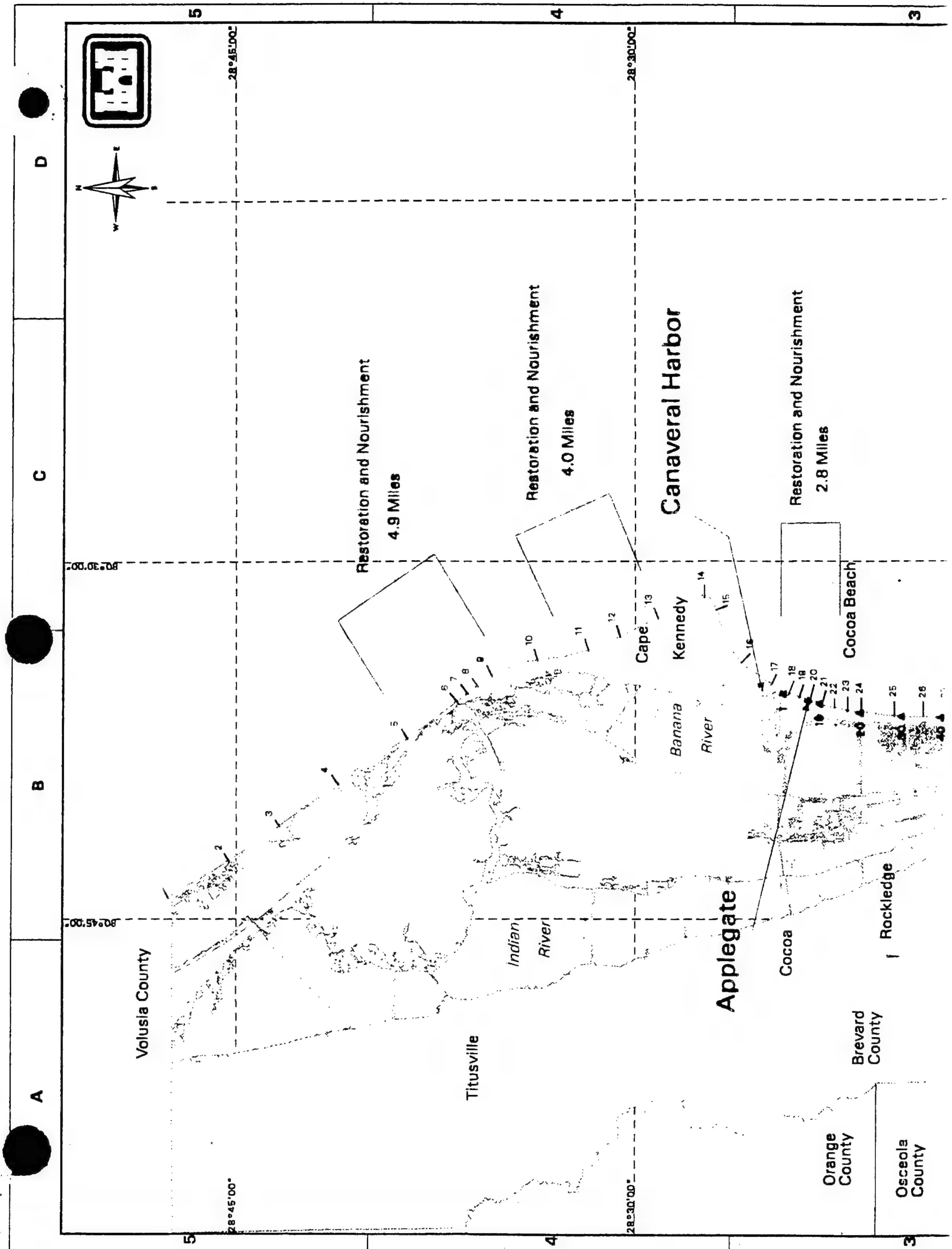


Figure F-2
Operation and Maintenance
Disposal Areas and Volumes



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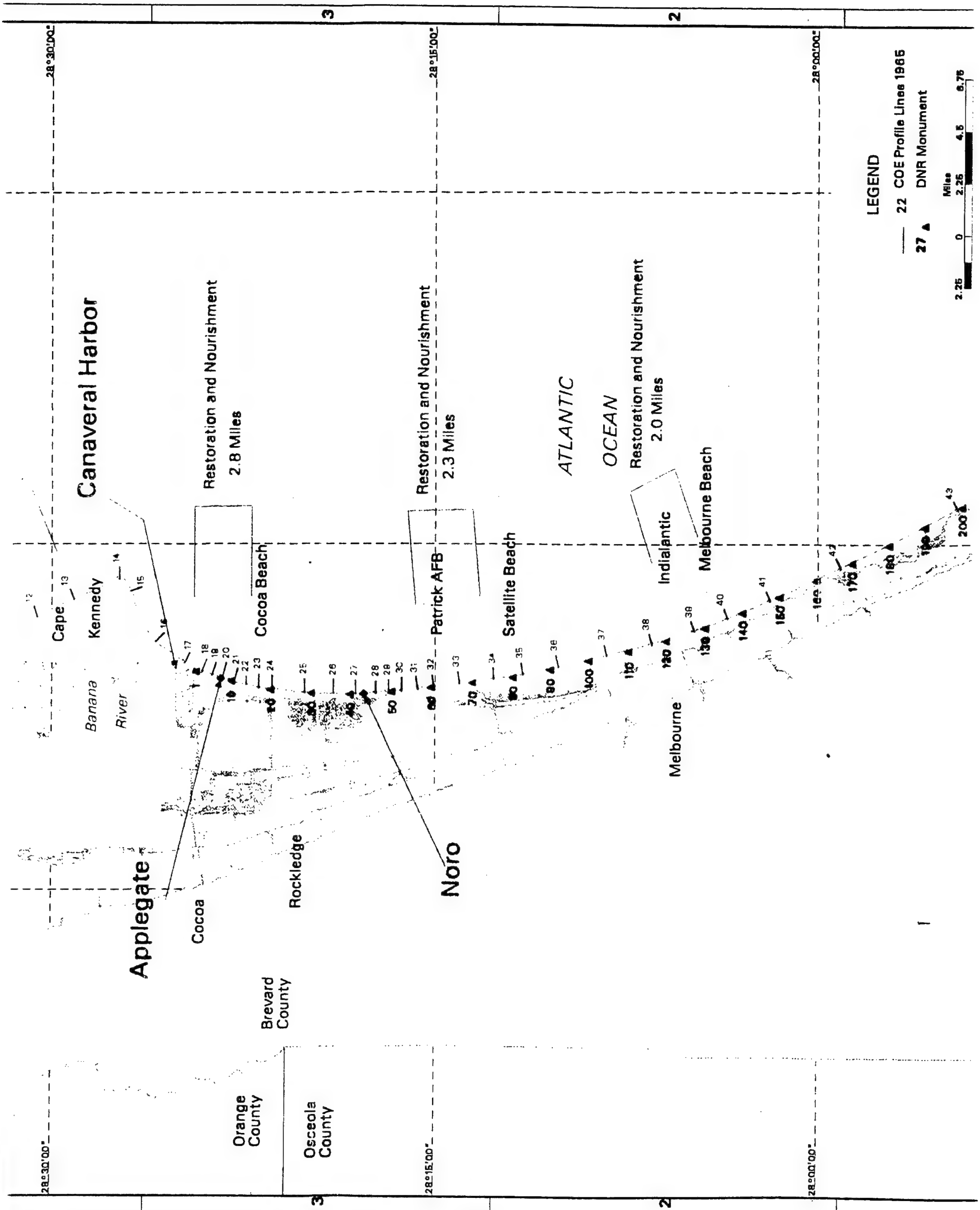
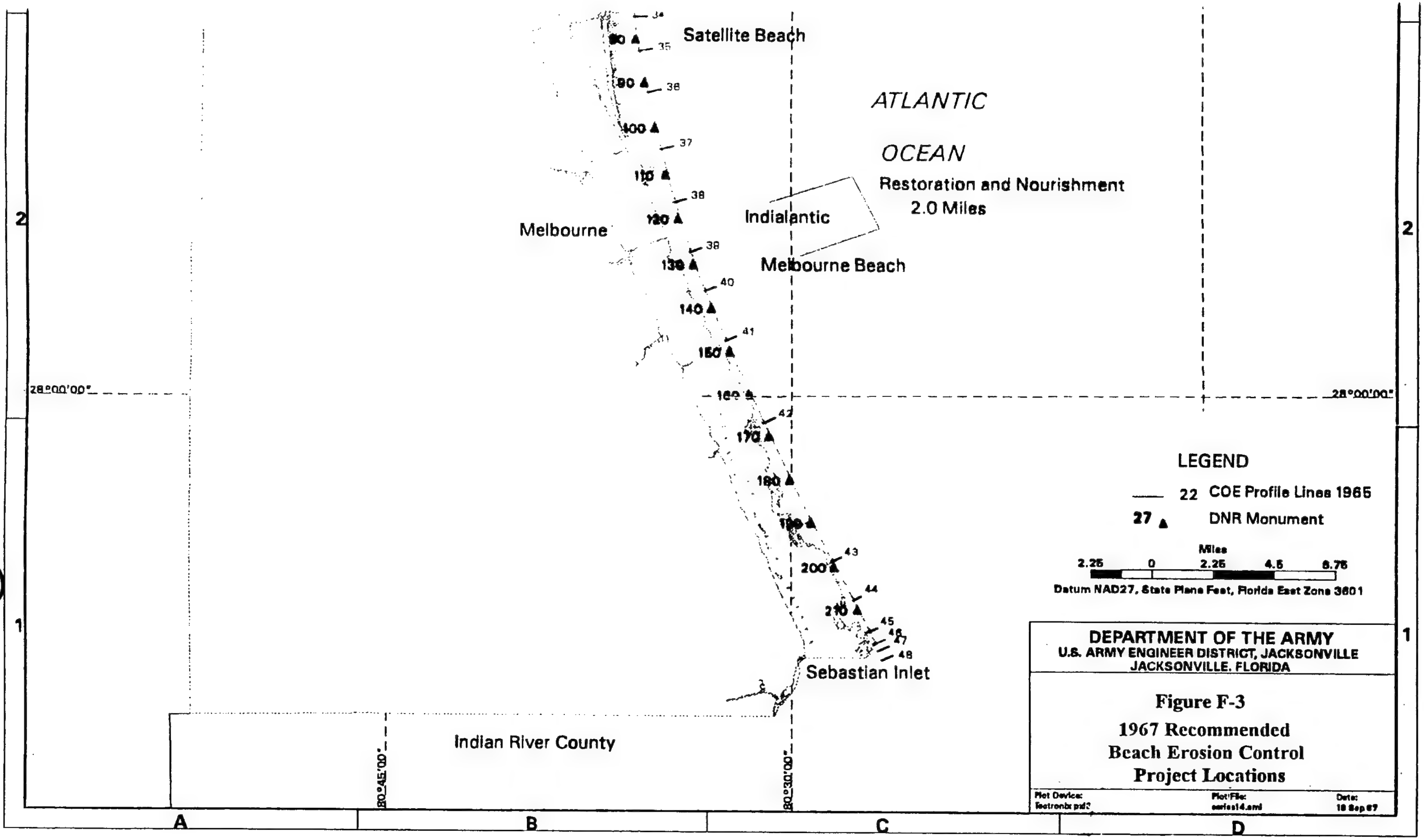

Canaveral Harbor
Restoration and Nourishment
2.8 Miles
Restoration and Nourishment
2.3 Miles
ATLANTIC
OCEAN
Restoration and Nourishment
2.0 Miles
Cape
Kennedy
Banana
River
Cocoa Beach
Patrick AFB
Satellite Beach
Indialantic
Melbourne Beach
Melbourne
Applegate
Noro
Cocoa
Rockledge
Brevard
County
Orange
County
Osceola
County
28°30'00"
28°15'00"
28°00'00"
LEGEND
22 COE Profile Lines 1965
27 DNR Monument
Miles
2.25
0
2.25
4.5
6.75

(2)



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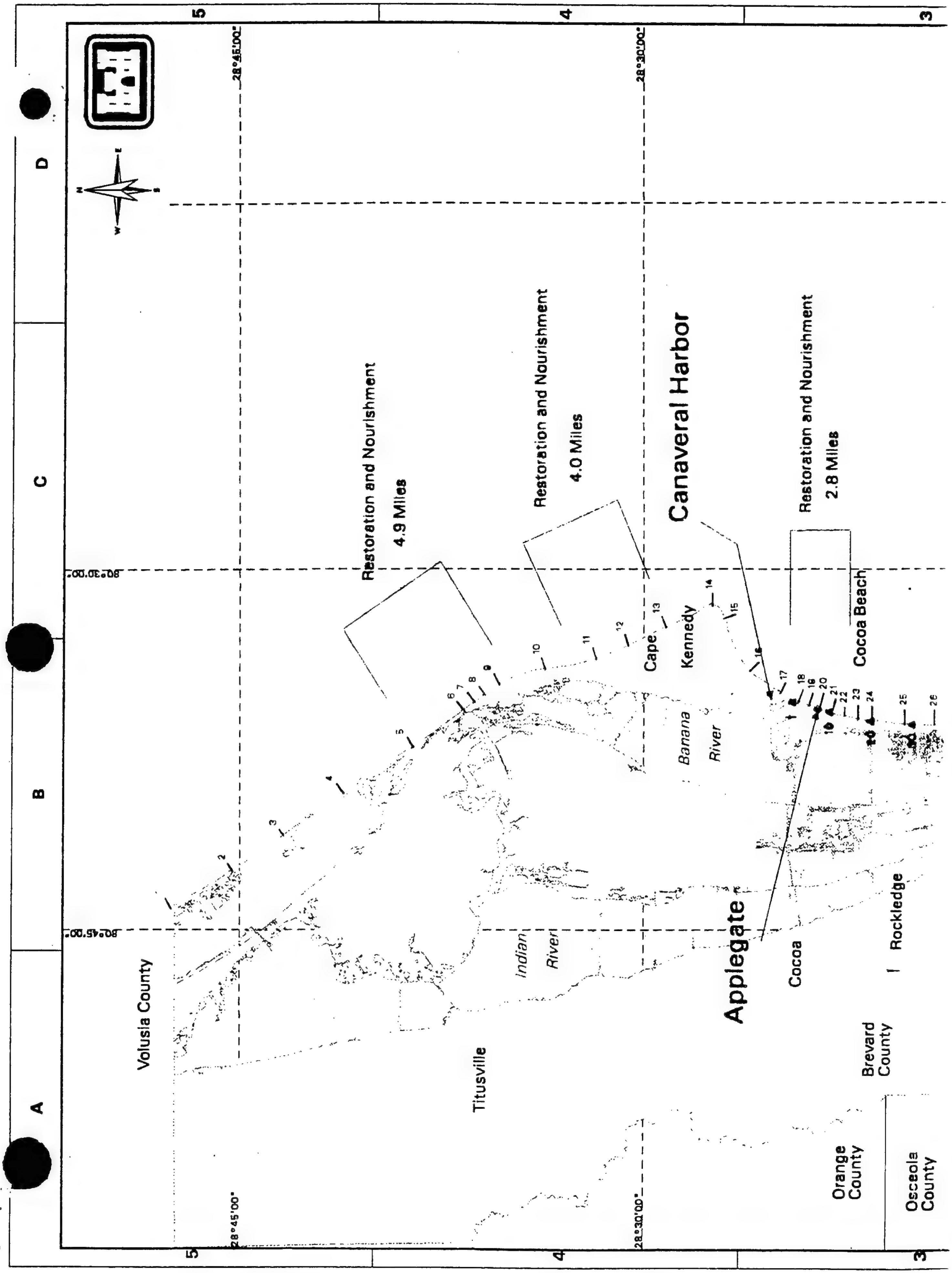
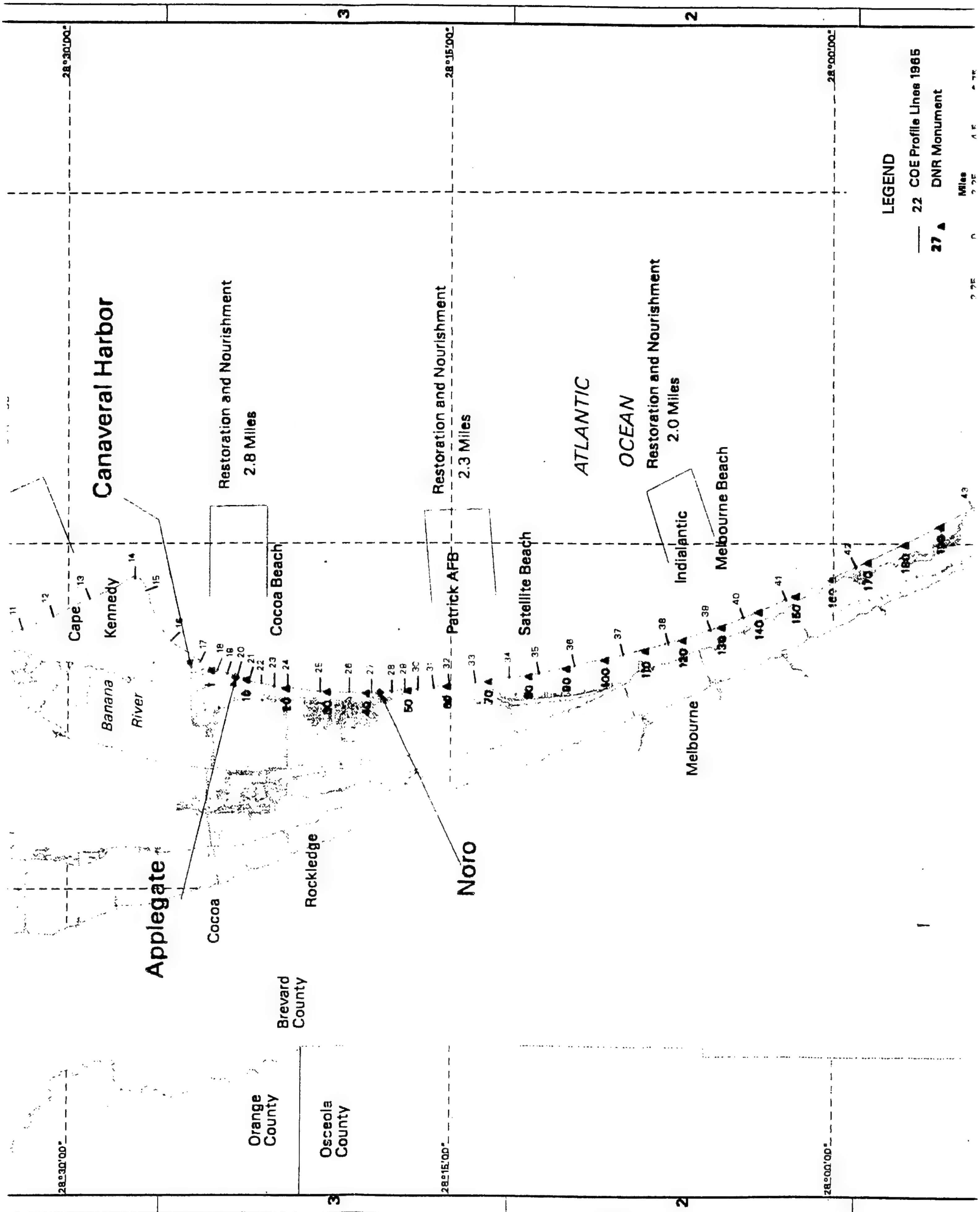
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
JACKSONVILLE, FLORIDA

Figure F-3
1967 Recommended
Beach Erosion Control
Project Locations

Date: 18 Sep 97

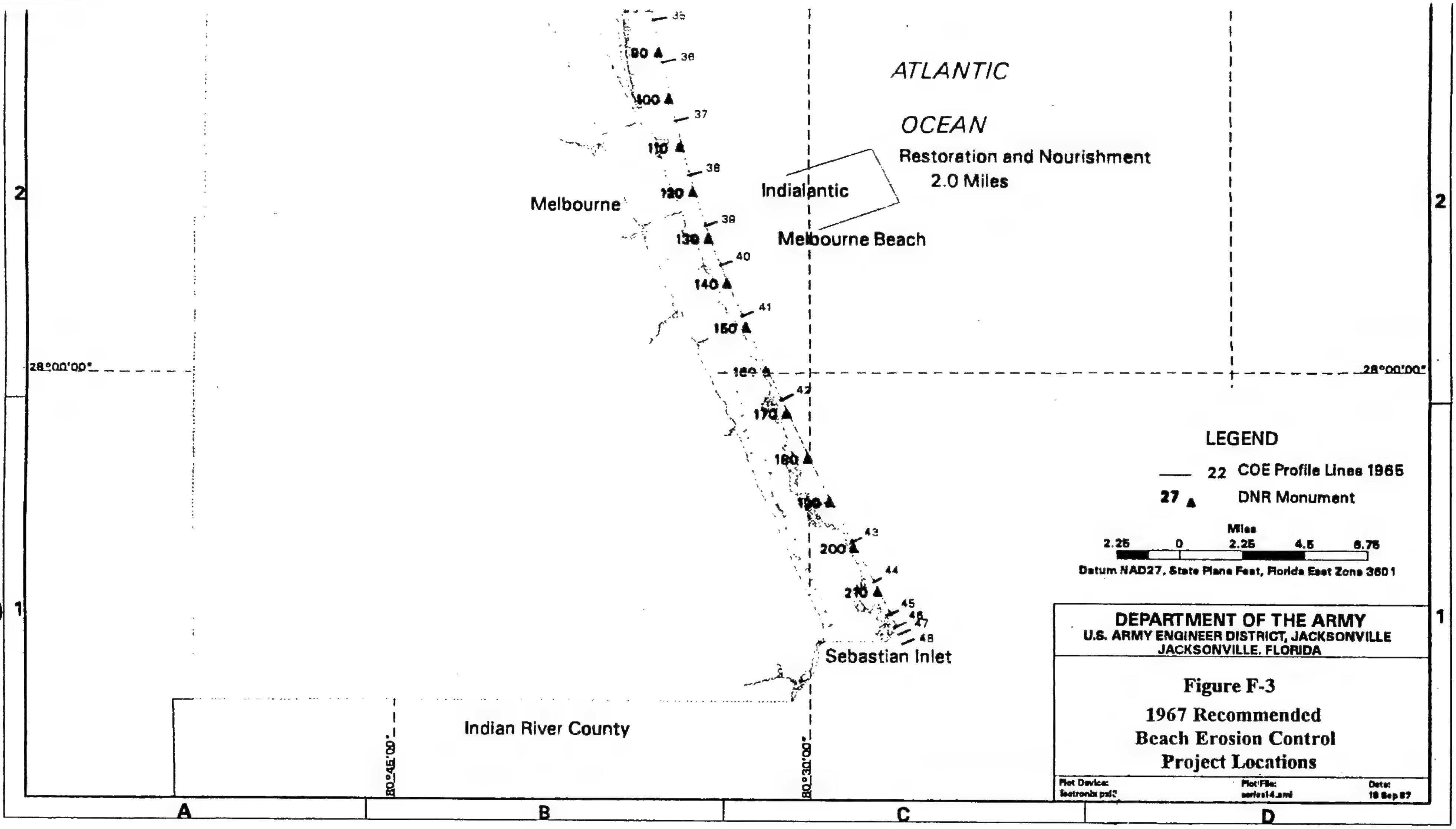
3


Restoration and Nourishment
4.9 Miles
Restoration and Nourishment
4.0 Miles
Canaveral Harbor
Restoration and Nourishment
2.8 Miles
Cocoa Beach
Cape
Kennedy
Banana
River
Indian
River
Applegate
Cocoa
Rockledge
Brevard
County
Titusville
Volusia County
Orange
County
Osceola
County
28°45'00"
28°30'00"
80°30'00"
80°45'00"
A
B
C
D
3
4
5



Canaveral Harbor
Restoration and Nourishment
2.8 Miles
Restoration and Nourishment
2.3 Miles
ATLANTIC
OCEAN
Restoration and Nourishment
2.0 Miles
Cape
Kennedy
Cocoa Beach
Patrick AFB
Satellite Beach
Indialantic
Melbourne Beach
Banana
River
Applegate
Cocoa
Rockledge
Noro
Melbourne
Brevard
County
Orange
County
Osceola
County
LEGEND
22 COE Profile Lines 1965
27 DNR Monument
28°30'00"
28°15'00"
28°00'00"
3
2

2



DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
JACKSONVILLE, FLORIDA

Figure F-3
1967 Recommended Beach Erosion Control Project Locations

Cape Canaveral. Restore 14,600 ft (2.8 miles) of beach at the city of Cape Canaveral. Volume needed for initial restoration was 988,000 cy. Approximately 240,000 cy would be needed annually for periodic nourishment (16.4 cy/ft). The sand-transfer plant was expected to transfer 315,000 cy of material across the inlet annually. Therefore, no periodic nourishment was authorized for the Cape Canaveral project segment.

Patrick AFB. Restore 10,600 ft (2.3 miles) of beach at Patrick AFB without Federal (Civil Works) participation. Federal agencies owning the property involved would be responsible for their own justification and funding for project construction. Volume needed for initial restoration was 700,000 cy. Approximately 82,000 cy would be needed annually for periodic nourishment (7.7 cy/ft).

Indialantic/Melbourne. Restore 10,600 ft (2.0 miles) of beach at Indialantic Beach and Melbourne Beach. Volume needed for initial restoration was 603,000 cy. Approximately 68,000 cy would be needed annually for periodic nourishment (6.4 cy/ft).

It is important to note that, with the exception of Cape Canaveral, all of the areas identified as having erosion problems were eroding at similar rates, between 6.4 and 7.7 cy/ft/year. Two of the eroding areas are located more than 9 miles north of Canaveral Harbor, to the north of Cape Kennedy, and are totally outside the zone of influence of the Harbor entrance.

Brevard County, Florida, Project Construction.

(*Cape Canaveral Segment*). About 2.0 of the 2.8-mile City of Cape Canaveral segment of the Brevard County, Florida, beach-erosion control project was completed in March 1975. Approximately 2.8 Mcy of sand were placed. In addition, about 1.3 Mcy were placed as part of the beach-erosion control project. The work was performed under an agreement dated April 26, 1973, and executed between the USACE and Brevard County Board of Commissioners (Contract No. DACW17-73-A-0009). The remaining 1.5 Mcy were placed on private property landward of the erosion control line (ECL) at Federal expense as a least-cost disposal site for new-work dredging as part of the deepening of the navigation entrance channel for the Trident. The southern 0.8 miles of the beach-erosion control project was not nourished as part of this work.

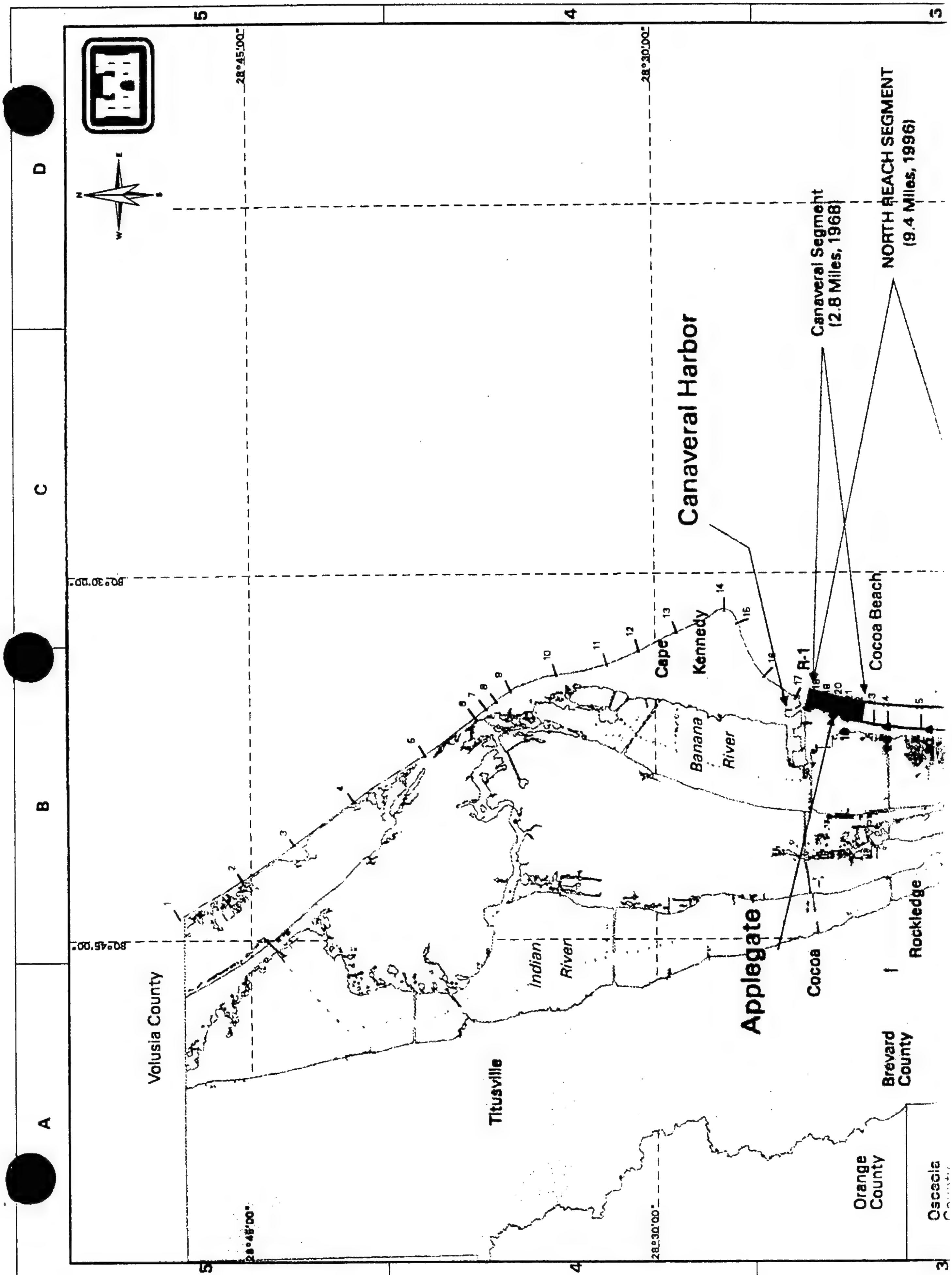
(*Indialantic/Melbourne Beach Segment*). The 2-mile Indialantic and Melbourne Beach Segment (R-122+500 ft to R-134+500 ft) of the Brevard County, Florida, beach-erosion control project was completed in 1981. About 540,000 cy were placed along 2 miles of beach. The contract above was amended in 1979 for this project segment. The project was authorized with a 50-year project life. Federal participation was limited by the authorizing act to 10 years from the completion of construction. Federal participation expired at the end of 1991.

F.3. Beach-Erosion Control Project Modifications

The House Public Works and Transportation Committee, by resolution adopted September 23, 1982, directed the USACE to review the report of the Chief of Engineers on Brevard County, Florida, published in House Document 352/90/2 to determine if the project should be modified. The purpose of the study was to consider the advisability of extending Federal participation in the Cape Canaveral and Indialantic and Melbourne Beach segments and the addition of other project segments if needed and justified. The study was completed and the report of the Chief of Engineers transmitted to the Secretary of the Army on December 23, 1996. Section 101(b)(7) of the 1996 Water Resources Development Act reauthorized the Brevard County, Florida, Shore-Protection Project based on the report of the Chief of Engineers. The City of Cape Canaveral segment was incorporated into a larger 9.4-mile segment. The Indialantic and Melbourne Beach segment was incorporated into a larger 3.4-miles segment. The locations of the existing and modified project segments are shown in Figure F-4. Beach restoration and periodic nourishment were authorized for both project segments at a 50-year total project cost estimated at $138,778,000.

F.4. Summary of Dredged-Material Placement

Approximately 4.8 Mcy of beach-quality dredged material from Canaveral Harbor have been placed on the beaches or in the nearshore littoral zone of Brevard County since April 1974. Another 792,700 cy have been placed at Patrick AFB by the Air Force. Non-Federal beach nourishment at the cities of Cape Canaveral and Cocoa Beach total 140,000 cy. The amounts, locations, authority, and other information on sand placed on Brevard County's beaches are shown in Figure F-5. In summary, 6.3 Mcy of beach-quality material have been placed on the beaches, or in the nearshore zone, south of Canaveral Harbor in Brevard County from 1965 through 1997. A summary of beach and nearshore disposal in Brevard County is given in Table F-2.



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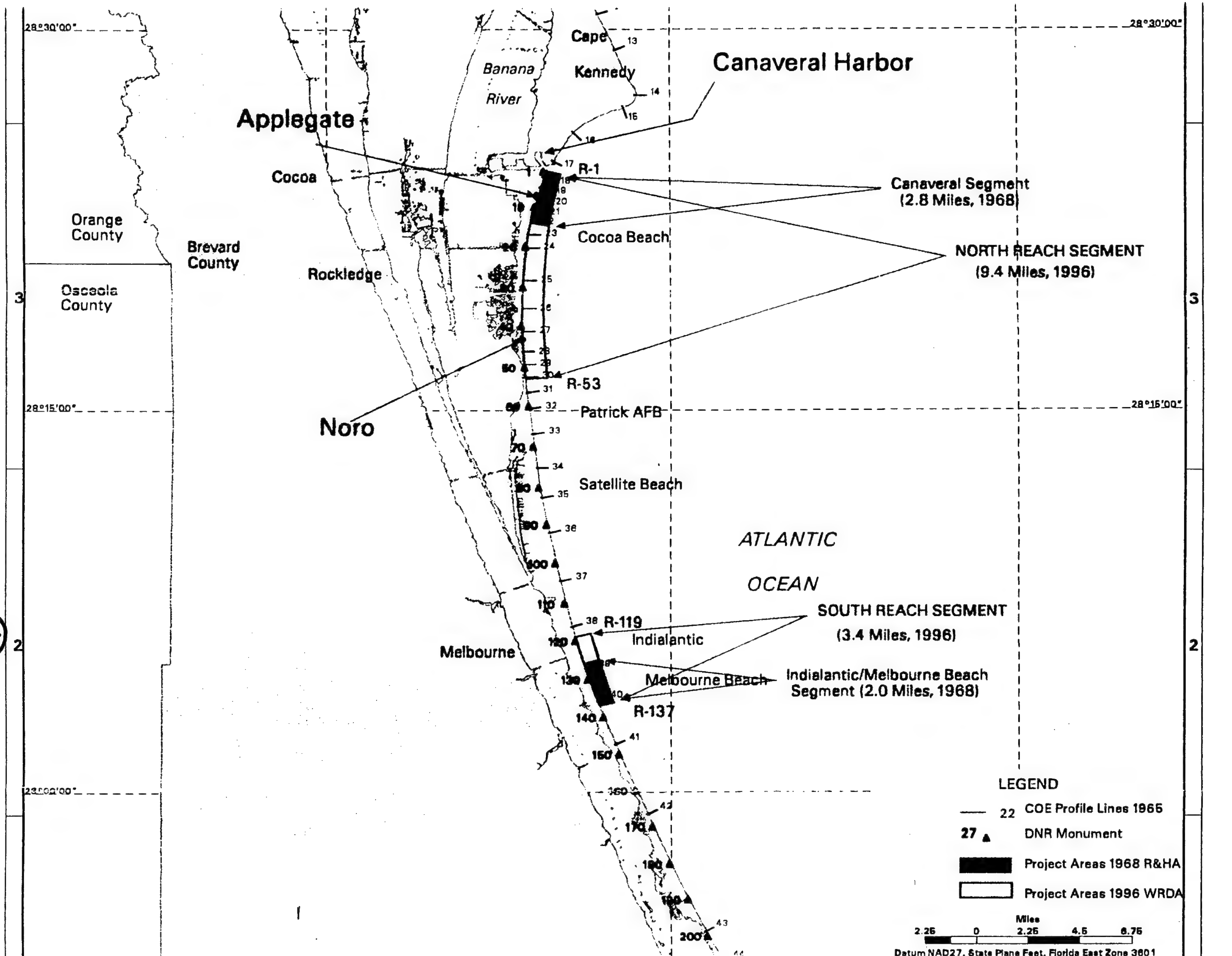

Canaveral Harbor
Applegate
Noro
Cape Kennedy
Banana River
Cocoa
Cocoa Beach
Rockledge
Orange County
Brevard County
Osceola County
Patrick AFB
Satellite Beach
Melbourne
Indialantic
Melbourne Beach
R-1
R-53
R-119
R-137
Canaveral Segment (2.8 Miles, 1968)
NORTH REACH SEGMENT (9.4 Miles, 1996)
SOUTH REACH SEGMENT (3.4 Miles, 1996)
Indialantic/Melbourne Beach Segment (2.0 Miles, 1968)
ATLANTIC OCEAN
28°30'00"
28°15'00"
LEGEND
22 COE Profile Lines 1965
27 DNR Monument
Project Areas 1968 R&HA
Project Areas 1996 WRDA
Miles
2.25 0 2.25 4.5 6.75
Datum NAD27, State Plane Feet, Florida East Zone 3601

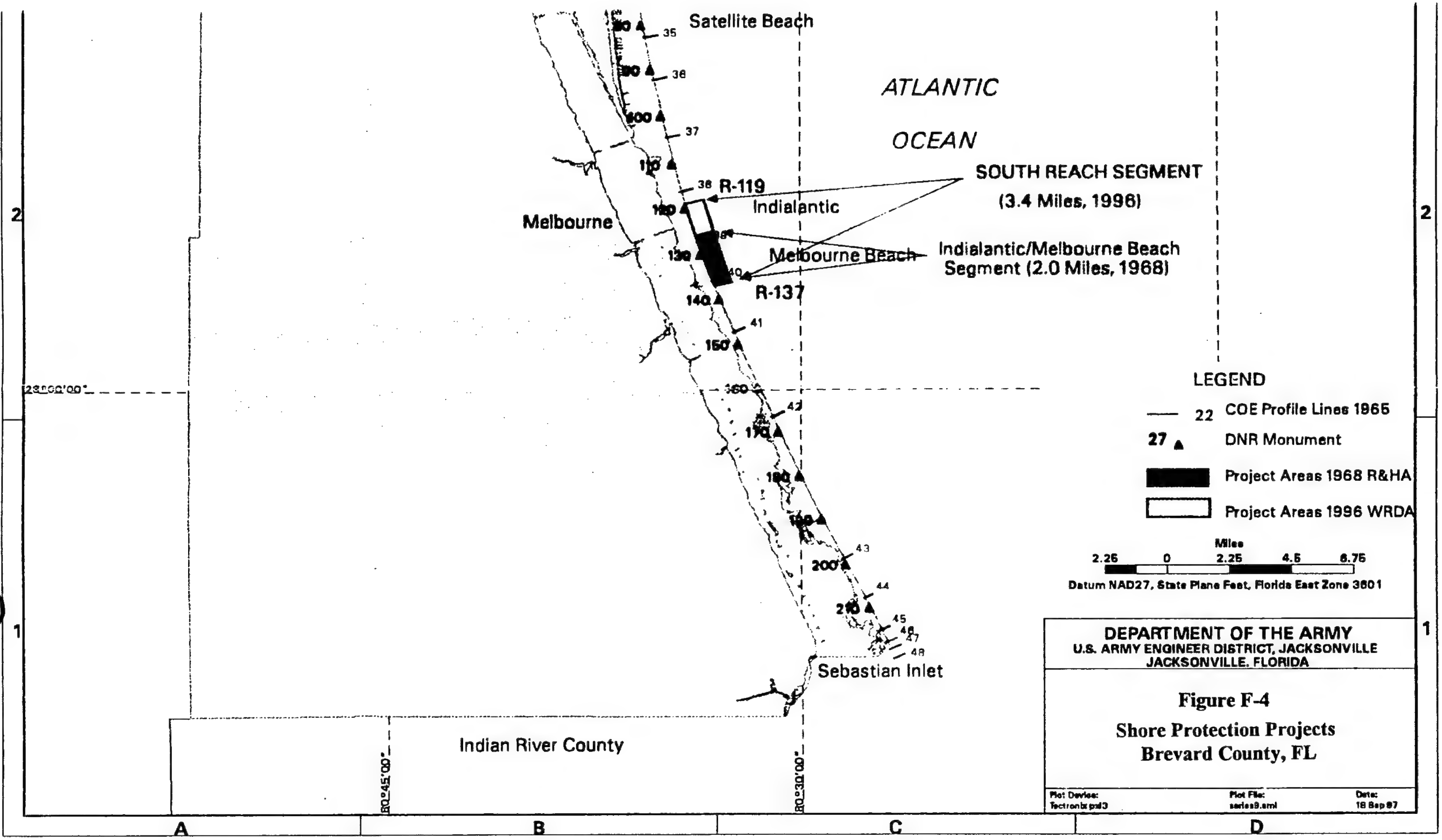
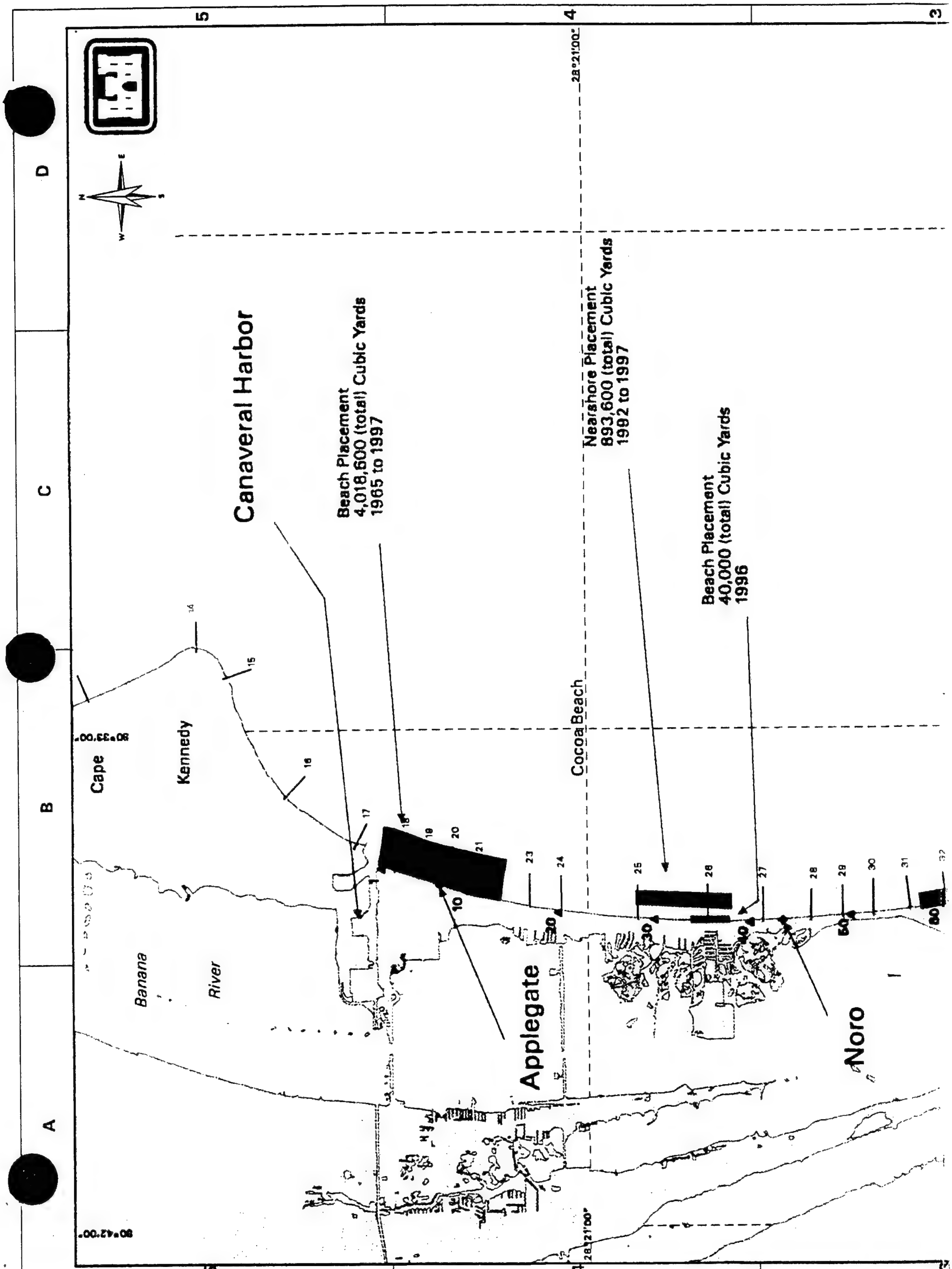


Figure F-4
Shore Protection Projects
Brevard County, FL



1

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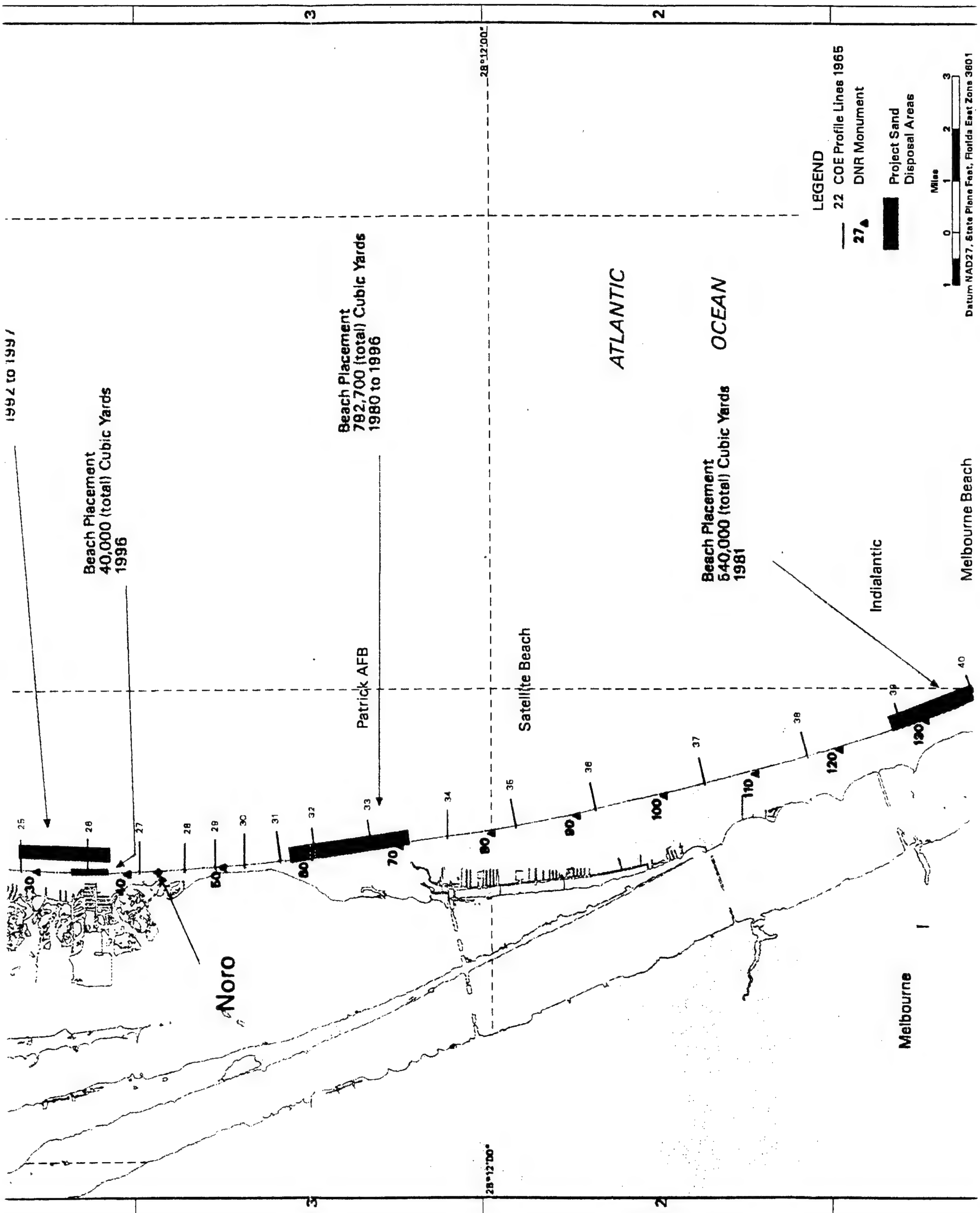


1992 to 1997
Beach Placement
40,000 (total) Cubic Yards
1996
Beach Placement
792,700 (total) Cubic Yards
1980 to 1996
Beach Placement
540,000 (total) Cubic Yards
1981
ATLANTIC
OCEAN
Patrick AFB
Satellite Beach
Indialantic
Melbourne Beach
Melbourne
LEGEND
22 COE Profile Lines 1965
27 DNR Monument
Project Sand
Disposal Areas
Miles
Datum NAD27, State Plane Feet, Florida East Zone 3601
28°12'00"

(2)

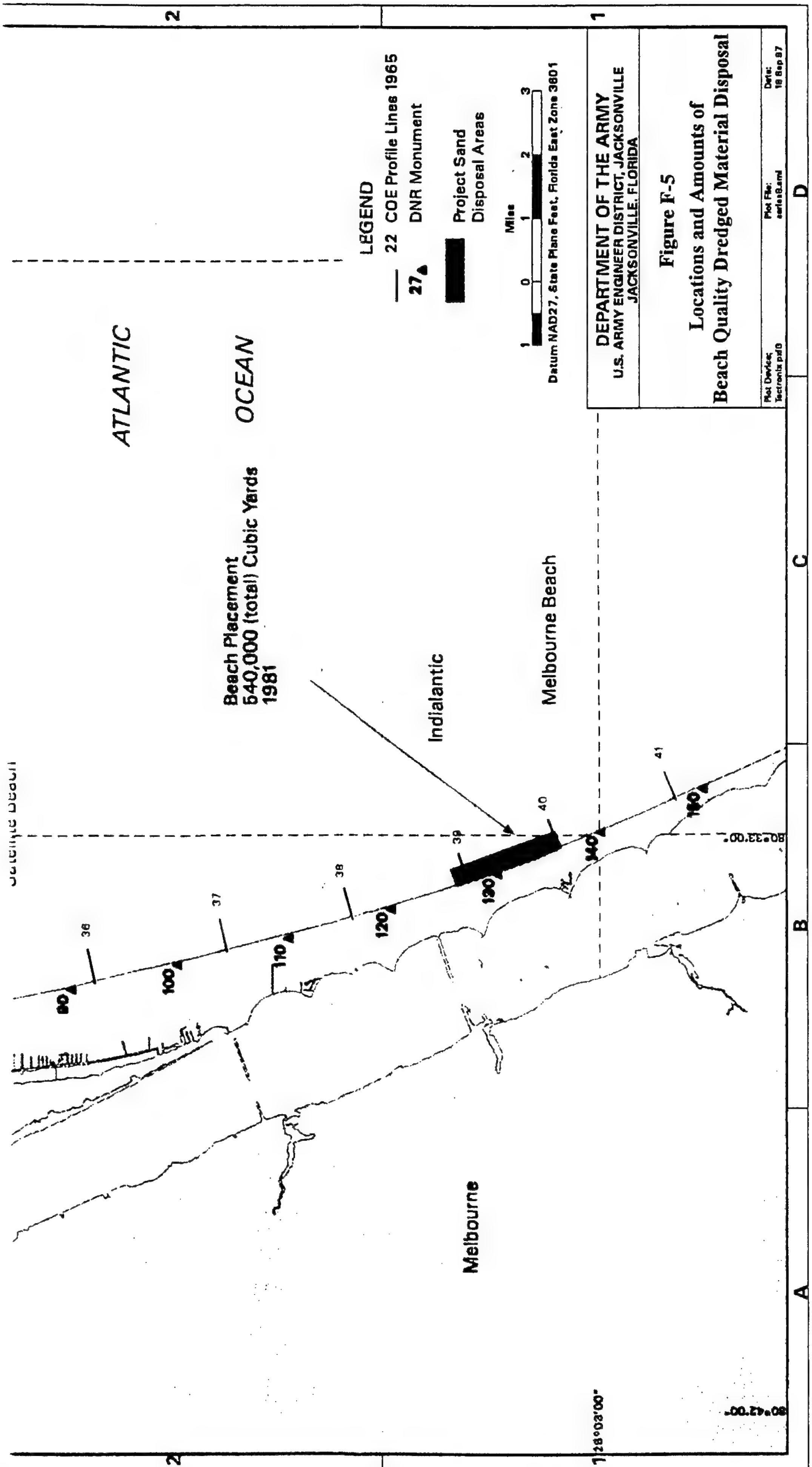

ATLANTIC
OCEAN
LEGEND
22 COE Profile Lines 1965
27 DNR Monument
Project Sand Disposal Areas
Miles
1 0 1 2 3
Datum NAD27, State Plane Feet, Florida East Zone 3601
DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
JACKSONVILLE, FLORIDA
Figure F-5
Locations and Amounts of
Beach Quality Dredged Material Disposal
Beach Placement
540,000 (total) Cubic Yards
1981
Indialantic
Melbourne Beach
Melbourne
36
37
38
39
40
41
90
100
110
120
130
140
150
80°33'00"
80°42'00"
28°03'00"
A
B
C
D
1
2

Table F-2. Summary of beach and nearshore disposal sites in Brevard County, Florida.								
Year	Location	Monument No. North Limit		South Limit	Authority/Purpose	Start Date	Complete Date	Volume of Sand Placed (cy)
1965	Cape Canaveral	R-2	to	R-4	Federal Navigation Project O&M / Beach Disposal	1965	1965	120,000
1972	Cape Canaveral	R-2	to	R-4	Federal Navigation Project O&M / Beach Disposal	Mar-72	Sep-72	200,000 *
1974-1975	Cape Canaveral	South Jetty	to	R-11	Federal Shore Protection Project / Beach Restoration	Apr-74	Mar-75	1,250,000
1974-1975	Cape Canaveral	South Jetty	to	R-11	Federal (Navy) Trident New Work / Beach Disposal	Apr-74	Mar-75	1,515,963
1980-1981	Indialantic/ Melbourne Bch	R-124	to	R-135	Federal Shore Protection Project / Beach Restoration Adv Nourishment	Oct-80	Jan-81	540,000
	(3rd Avenue in Indialantic to 5th Avenue in Melbourne Beach)							
1992	Cocoa Beach	R-28	to	R-31	Federal Navigation Project O&M / Nearshore Disposal	Jun-92	Aug-92	229,000 **
1993	Cocoa Beach	R-28	to	R-31	Federal Navigation Project O&M / Nearshore Disposal	Jul-93	Nov-93	180,410
1994	Cape Canaveral	R-5	to	R-11	Local Beach Nourishment City/Port Authority Co-Sponsors	Feb-94	Apr-94	100,000 **
1994	Cocoa Beach	R-28	to	R-31	Federal Navigation Project O&M / Nearshore Disposal	Oct-94	Oct-94	91,310
1994	Cocoa Beach	R-28	to	R-31	Federal Navigation Project O&M / Nearshore Disposal	Oct-94	Nov-94	69,850
1995	Cape Canaveral	R-0	to	R-8	Federal Navigation Project Sand Bypass / Beach Disposal	Jan-95	May-95	831,642
1995	Cocoa Beach	R-28	to	R-31	Federal Navigation Project O&M / Nearshore Disposal	Aug-95	Dec-95	322,990
1996	Cocoa Beach	R-34	to	R-38	Local Beach Nourishment City/Port Authority Co-Sponsors	Feb-96	Mar-96	40,000
1980-1996	Patrick AFB	R-53	to	R-75	Military, Dune Restoration Ten Placements	1980	1996	792,698
							TOTAL	**6,284,863**

Notes: * From a total of 341,954 dredged from the turning basin.
** Best estimates from field observations. The 1993 volume ranges from 180,000 to 218,000 estimated.

F.5. Analysis of Volume Changes From 1951 To 1997

This section summarizes the location and analysis of available beach-profile survey data north and south of Canaveral Harbor in Brevard County, Florida. Comparisons are made between plaintiffs' claims of volume losses and estimates of volume losses based on survey data.

F.5.1. Survey Datum

Beach-profile survey data for Brevard County, Florida, have been acquired both by the Florida Department of Environmental Protection (FDEP) and by the USACE. The FDEP survey data are collected for the State's Coastal Construction Control Line (CCCL), erosion control, and inlet management programs. The USACE has acquired beach-profile surveys for the purposes of navigation, beach-erosion control, and shore protection. From March to June 1965, the USACE conducted a countywide beach-profile survey of Brevard County. The USACE Beach Profile Lines 1-17 are located north of the inlet. Profile Lines 18 to 48 are located from the south jetty to just south of Sebastian Inlet. The FDEP survey data are referenced to R-1, R-2, etc. The USACE and FDEP profile locations are shown in Figure 2-1 of the main text.

The FDEP survey data are referenced to the 1929 National Geodetic Vertical Datum (NGVD 29). All survey data acquired by the USACE (Jacksonville District) for Canaveral Harbor and Brevard County are referenced to a construction datum (mean low water (MLW)) which is -1.9 ft below NGVD 29. The National Ocean Service (NOS) datum in the main text of this report is based upon a specific tidal epoch. Therefore, NOS datums are subject to change throughout time. The USACE has adopted the -1.9-ft offset to define an invariant construction datum. The survey data and analysis described in this appendix are referenced to NGVD 29.

F.5.2. Canaveral Harbor Monitoring Surveys

Numerous hydrographic surveys of the Harbor channel, turning basins, and adjacent areas have been performed over the years as part of the operation and maintenance (O&M) of the Harbor. The purpose of these hydrographic surveys is to monitor shoaling in the entrance channel, inner channel, access channels and turning basins, and determine pre-dredging and post-dredging conditions. The O&M hydrographic surveys are generally limited in scope to the Harbor project dimensions and cannot be used to determine changes to the adjacent beaches.

The USACE established monitoring surveys as part of the Canaveral Harbor project. The Jacksonville District Office (D.O.) File Numbers for beach-profile surveys for the Harbor project are listed in Table F-3. The first survey was performed from September to October 1951, prior to the pilot cut through the Barrier Island. The 1951 survey extended 10,500 ft north and south of the Harbor. These distances are referred to as Station 105+00N and 105+00S, respectively. The stationing for the October 1951, survey is shown on Plate F-1. Monitoring surveys were taken in

April and August 1952, but these surveys were limited to the area between 20+00N and 25+00S. In April 1953, a limited number of beach profiles were taken from 20+00N to 30+00S.

Table F-3. Canaveral Harbor, Florida, Federal Navigation Project monitoring surveys.

D.O. File No.	No. of Sheets	Survey Dates	Description
11-20, 193 Ocean Shoreline and Beach Profiles	3	Oct-51	Baseline control and beach-profile surveys, 23 lines from 105+00N to 105+00S. Offshore surveys extend to -18 ft (MLW).
11-21, 091 Erosion/Accretion, April-Aug 1952	1	Apr-52 to Aug-52	Volume contours plotted for surveys. Coverage limited to 20+00N to 25+00S.
11-21, 964	1	Jan-52	Layout of north and south jetties, MHW shorelines for limited area north and south.
11-22, 041 Periodic Survey of Channel and Beaches	3	Apr-53	Beach-profile surveys, 22 lines from 50+00N to 105+00S. Offshore surveys extend to -18 ft (MLW). Profile Lines 13+00N to Rgs. -600 have limited offshore coverage.
11-22, 654 Periodic Survey of Channel and Beaches	5	May-54 to Oct-56	Baseline control and beach-profile surveys, 32 lines from 210+00N to 343+99S. Offshore surveys extend to -20 ft (MLW).
11-22, 726 MHW Shoreline Changes	1	Oct-51 to May-54	Plan view of MHW shoreline changes for 105+00N to 105+00S.
11-23, 442 Erosion and Accretion	4	Apr-52, Aug-52 Apr-53, May-54 Jun-55	Limited survey coverage in immediate vicinity of entrance channel.
11-23, 992 Canaveral Harbor Shoreline Vicinity of the North Jetty	2	Apr-56 Jul-56	Beach-profile surveys from Sta. 4+00N to Sta. 2+00N.
11-24, 397 High-Water Shoreline Changes 1878-1958	5	1878 to 1901 1928 to 1930 1952 to 1954 1955 to 1956 1957 to 1958	High-water shorelines from surveys listed, in plan view. High-water shoreline comparisons for 16 miles north of Harbor to 19 miles south of Canaveral Harbor.
11-24, 653 MHW Shoreline Changes	1	May-54 Oct-56 Nov-58	Limited MHW shoreline changes from south jetty to 1,000 ft
11-25, 726 Beach-Profile Surveys of 1954, 1956, 1958	8	May-54 Oct-56 Nov-58	Beach-profile surveys 32 lines fr 210+00N to 343+99S. 1954, 1956 offshore surveys extend to -20 ft (MLW). 1958 offshore survey extends to -30 ft (MLW).
11-31, 614 Canaveral Beach Nourishment Study	4	Feb-72 Sep-72	Profile control and layout for Profile Lines 3 to 29.
11-31, 661 P&S Survey, First Sand Bypass	34	Feb-94 to Apr-94	Surveys CCAFS-29 to CCAFS-42 north of Harbor, R-0 to R-15 south of the Harbor. Beach-profile surveys.
11-36, 999	29	Jun-95	Surveys CCAFS-29 to CCAFS-42 north of Harbor, R-0 to R-15 south of Harbor. Beach-profile surveys.
11-37, 018 Sand Bypass System, Phase II	14	Jan-95 to Feb-95	Surveys CCAFS-29 to CCAFS-42 north of Harbor, R-0 to R-15 south of Harbor. Beach surveys.
11-37, 059 Monitoring Survey	29	Oct-95	Surveys CCAFS-29 to CCAFS-42 north of Harbor, R-0 to R-15 October Monitoring Survey
11-37, 146 Monitoring Survey	29	Jan-96 to Feb-96	Surveys CCAFS-29 to CCAFS-42 north of Harbor, R-0 to R-15 south of Harbor. Beach-profile surveys.
11-37, 296 Monitoring Survey	24	May-96	Surveys CCAFS-29 to CCAFS-42 north of Harbor, R-0 to R-15 south of Harbor. Beach surveys.
11-37, 442 Monitoring Survey	27	May-97	Surveys CCAFS-29 to CCAFS-42 north of Harbor, R-0 to R-15 south of Harbor. Beach-profile surveys.

In May 1954, the October 1951 survey was repeated and expanded. Coverage was extended north (105+00N to 210+00N) and south (105+00S to 343+98S) of the Harbor. From October to November 1956, the monitoring surveys were repeated from 210+00N to 165+03S. Between November 1958 and January 1959 (referred to as the 1958 survey), the 1954 monitoring surveys were repeated (210+00N to 343+98S).

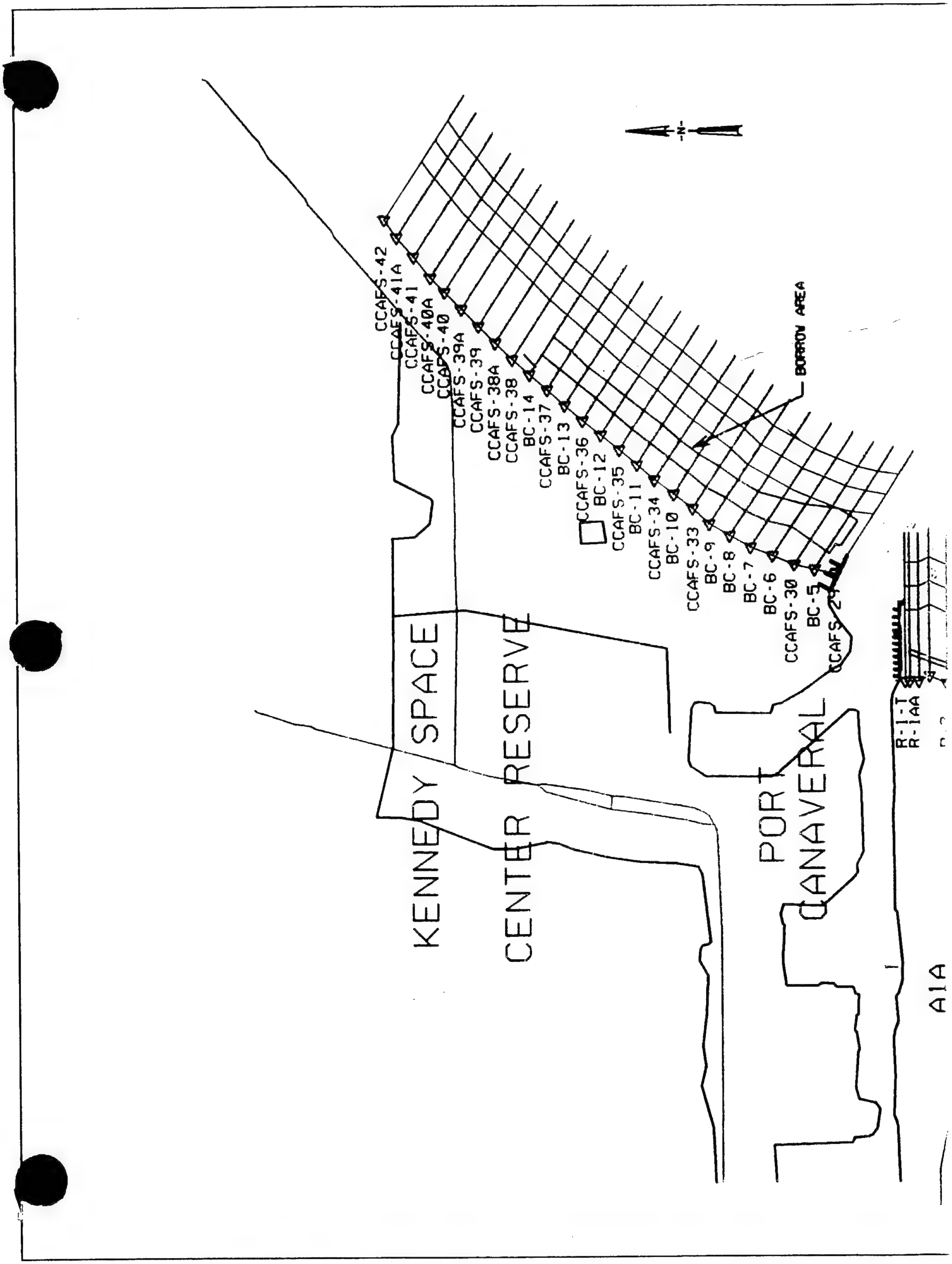
In March 1972, pre-dredging surveys were taken for the area 4+00N through 23+00S, in 100-ft increments. The March 1972 survey coverage offshore was limited to about -12 ft MLW. In September 1973; July, August, and November 1974; and in January, February, and May 1975, surveys were taken as part of the Trident work. The September 1973 and the July, August, and November 1974 surveys extended from 20+00N to 60+00S (R-6). The January and February 1975 surveys extended from 20+00N to 90+00S (R-9). The May 1975 survey extends from 20+00N to R-12.

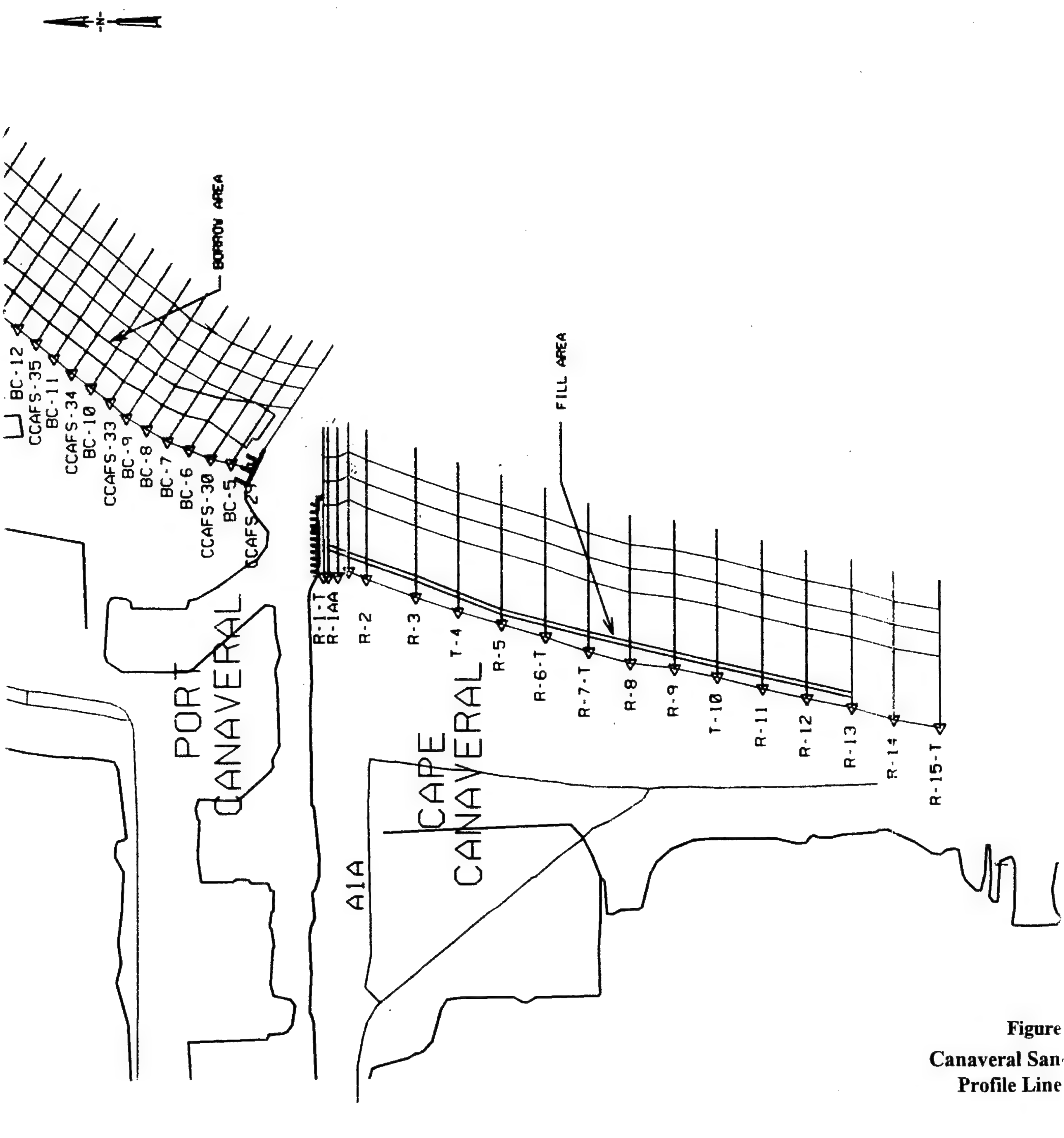
The USACE conducted sand-bypassing monitoring surveys in January 1995 (pre-), June 1995 (post-), October 1995, January 1996, May 1996, May 1997, and December 1997. The surveys extend from the south jetty to R-15, south of the Harbor, and from the north jetty to CCAFS-42 (approximately 135+00N) north of the Harbor. Figure F-6 shows the extent of the survey coverage for the sand-bypass monitoring profiles. These survey lines are shown relative to other survey lines in Table F-4 for the area north of the Harbor and in Tables F-5 and F-6 for the area south of the Harbor.

F.5.3. Brevard County Beach-Erosion Control Surveys

Numerous beach-profile surveys of the beaches of Brevard County have been performed by the USACE. These surveys were made for shore-protection studies, and for pre- and post-project construction and project monitoring. The Jacksonville District Office (D.O.) File Nos. for USACE beach-profile surveys for the Brevard County, Florida, shore protection project and related studies are listed in Table F-7. Unlike the USACE surveys taken for Canaveral Harbor project which start with a D.O. File No. 11 (Table F-3), the surveys taken for the Brevard County shore protection project start with D.O. File No. 24.

Between March and June 1965, the USACE conducted a countywide beach-profile survey of Brevard County for the feasibility study. USACE Beach Profiles 1-17 are located north of the inlet. Profile Lines 18 to 48 are located from the south jetty to just south of Sebastian Inlet. From May to June 1971, a limited number of USACE beach-profile lines (8) were surveyed from 5,000 ft north and south of the Harbor. In February and August 1972, 29 beach-profile surveys were taken for an area 5,000 ft north to 14,800 ft south of the Harbor. In November 1974, USACE Profile Lines 30, 31, 32, 33, and 43 were surveyed; however, the lines only extend offshore to the -10-ft contour. These lines are located on or near Patrick AFB.


KENNEDY SPACE
CENTER RESERVE
PORT
CANAVERAL
BORROW AREA
N
CCAFS-42
CCAFS-41A
CCAFS-41
CCAFS-40A
CCAFS-40
CCAFS-39A
CCAFS-39
CCAFS-38A
CCAFS-38
BC-14
CCAFS-37
BC-13
CCAFS-36
BC-12
CCAFS-35
BC-11
CCAFS-34
BC-10
CCAFS-33
BC-9
BC-8
BC-7
BC-6
CCAFS-30
BC-5
CCAFS-29
CCAFS
R-1-T
R-1AA
A1A



Figure

Canaveral San

Profile Line

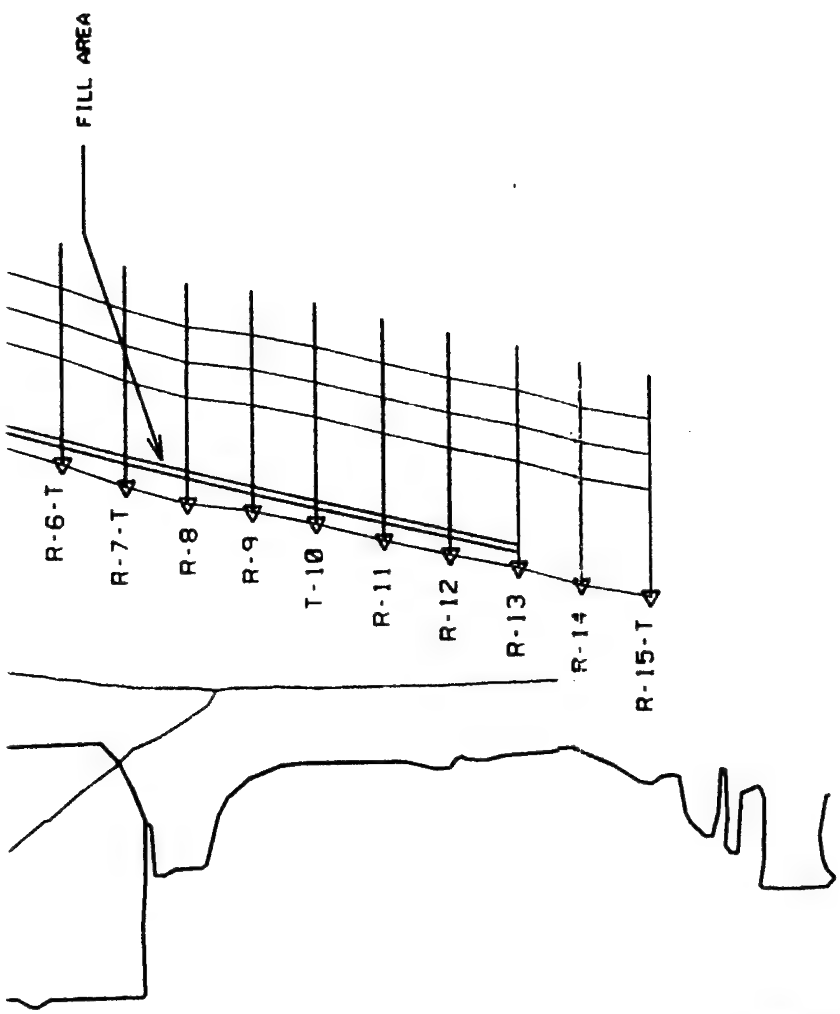


Figure F-6
Canaveral Sand By-Passing
Profile Line Locations

Table F-4. Beach-profile surveys north of Canaveral Harbor.

USACE Canaveral Harbor Beach-Profile Survey Line Number		USACE Beach-Erosion Control Profile Line No.		Distance from Harbor Channel Centerline, ft	USACE Canaveral Harbor Monitoring Surveys				USACE BEC Survey	USACE Canaveral Harbor Sand-Bypassing Monitoring Surveys						
					Oct-51	May-54	Oct-56	Nov-58	Mar-65 to Jan-66	Feb to Apr-94	Jan-95 to Feb-95	Jun-95	Oct-95	Jan-96	May-96	May-97
CAPE CANAVERAL																
			(7) P-15						X							
210+00N				21,000		X	X	X								
165+00N				16,500		X	X	X								
	CCAFS-42									X	X	X	X	X	X	X
135+00N				13,500		X	X	X								
	CCAFS-41A									X	X	X	X	X	X	X
	CCAFS-41									X	X	X	X	X	X	X
	CCAFS-40A									X	X	X	X	X	X	X
	CCAFS-40									X	X	X	X	X	X	X
	CCAFS-39A									X	X	X	X	X	X	X
	CCAFS-39									X	X	X	X	X	X	X
105+00N			(8) P-16	10,500	X	X	X	X	X							
	CCAFS-38A									X	X	X	X	X	X	X
	CCAFS-38									X	X	X	X	X	X	X
	BC-14									X	X	X	X	X	X	X
90+00N				9,000	X											
	CCAFS-37									X	X	X	X	X	X	X
	BC-13									X	X	X	X	X	X	X
	CCAFS-36									X	X	X	X	X	X	X
75+00N				75,000	X	X	X	X								
	BC-12									X	X	X	X	X	X	X
	CCAFS-35									X	X	X	X	X	X	X
	BC-11									X	X	X	X	X	X	X
60+00N				6,000	X											
	CCAFS-34									X	X	X	X	X	X	X
	BC-10									X	X	X	X	X	X	X
50+00N		Line 3		5,000	X	X	X	X								
			P-16C													
	CCAFS-33									X	X	X	X	X	X	X
	BC-9									X	X	X	X	X	X	X
40+00N				4,000	X											
	BC-8	Line 4								X	X	X	X	X	X	X
	BC-7	Line 5								X	X	X	X	X	X	X
30+00N				3,000	X	X	X	X								
	BC-6	Line 6								X	X	X	X	X	X	X
	CCAFS-30	Line 7								X	X	X	X	X	X	X
20+00N			(9) P-17	2,000	X	X	X	X	X							
	BC-5									X	X	X	X	X	X	X
17+00N		Line 8		1,700												
15+00N				1,500	X	X	X	X								
13+00N				1,300		X	X	X								
	CCAFS-29									X	X	X	X	X	X	X
12+00N	**Centerline of North Jetty**															

Note: Columns with shading denote surveys that were used in the volume analysis and plotted on the plates at the end of Appendix F.

Table F-5. Beach-profile surveys south of Canaveral Harbor from south jetty to R-53, October 1951 to May 1975.

DEP Survey Mon. Number	USACE Canaveral Harbor Beach Profile Survey Line Number	USACE Beach-Erosion Control Profile Line No.		Distance from Harbor Channel Centerline, ft	USACE Canaveral Harbor Monitoring Surveys Month/Year of Survey				USACE BEC Survey	USACE Beach-Erosion Control Surveys		DEP CCCL Survey	USACE Trident Survey
					Oct-51	May-54	Oct-56	Nov-58	Mar-65 to Jan-66	May, Jun, Sep-71	Feb, Aug, Sep-72	Sep-72 to Nov-72	May-75
Range 400, Centerline of South Jetty													
	Range 550			700		X							
R-0													
	Range 600			750		X	X	X					
		P-17A								X			X
	Range 800			950		X	WD	X					X
	CDA-B, P9	Line 9	P-17A1								X		X
	10+OOS			1,000	X								
R-1												X	
	CDA-B, P9A												X
R-1AA													
	CDA-B,P10	Line 10									X		X
	Range 1000			1,150		X	WD	X					
R-1A													
	15+00S			1,500	X	X	X	X					
	Range 1200			1,350		X	X	X					
	Range 1400			1,550		X	WD	X					
	CDA-B, P10A												X
		P-17B								X	X		X
R-2	CDA-B, P11	Line 11									X	X	
	20+00S			2,000	X								
	CDA-B,P11A												X
	CDA-B, P12	Line 12									X		X
	25+00S	P-18 Alt	PL-18	2,500		X	X	X	X	X	X		X
	CDA-B, P12A												X
	CDA-B, P13	Line 13									X		X
	30+00S			3,000	X								
R-3												X	
	CDA-B, P13A												X
	CDA-B, P14	Line 14									X		
		P-18A	PL-18							X	X		X
	CDA-B, P14A												X
R-4												WD	
	40+00S			4,000	X								
	CDA-B, P-15	Line 15									X		
		P-18B								X			
	CDA-B, P15A												X
	CDA-B, P16	Line 16									X		
R-6	50+00S	P-19	PL-19	5,000	X	X	X	X	X	X		WD	
	CDA-B, P17	Line 17									X		
	CDA-B, P17A												
	CDA-B, P18	Line 18									X		
R-6	CDA-B, P18A											X	
	60+00S	P-19A		6,000	X					X			
	CDA-B, P19	Line 19									X		
	CDA-B, P19A												X
	CDA-B, P20	Line 20									X		

Table F-5. Beach-profile surveys south of Canaveral Harbor from south jetty to R-53, October 1951 to May 1975.												
DEP Survey Mon. Number	USACE Canaveral Harbor Beach Profile Survey Line Number	USACE Beach-Erosion Control Profile Line No.		Distance from Harbor Channel Centerline, ft	USACE Canaveral Harbor Monitoring Surveys Month/Year of Survey				USACE BEC Survey	USACE Beach-Erosion Control Surveys		DEP CCCL Survey	USACE Trident Survey
					Oct-51	May-54	Oct-56	Nov-58	Mar-65 to Jan-66	May, Jun, Sep-71	Feb, Aug, Sep-72	Sep-72 to Nov-72	May-75
R-7				6,698						X		WD	
	CDA-B, P20A			**Applegate**									X
		P-20B											
	75+00S		PL-20	7,500	X	X	X	X	X				
	CDA-B, P21	Line 21									X		
R-8	CDA-B, P21A											WD	X
	CDA-B, P21B												X
	CDA-B, P21C												X
			20A							X			
R-9	CDA-B, P22	Line 22									X	X	
	90+00S			9,000	X								
	CDA-B, P22A												X
	CDA-B, P22B												X
			20B							X			
R-10	CDA-B, P23	Line 23									X	WD	X
	CDA-B, P23A												X
	CDA-B, P23B												X
	105+00S		PL-21	10,500	X	X	X	X	X	X			
R-11	**South limit of Trident Fill**											WD	
	CDA-B, P24	Line 24									X		X
	CDA-B, P24A												
	CDA-B, P24B												X
	CDA-B, P24C												X
R-12												X	
		Line 25	21A							X	X		
R-13												WD	
		Line 26									X		
	133+84S		PL-22	13,384		X	X	X	X	X			
R-14												WD	
		Line 27									X		
		Line 28	22B							X	X		
R-15				14,784	2.8 mi							X	
		Line 29	22C							X	X		
R-16				15,500								WD	
R-17	165+03S		PL-23	16,503		X	X	X	X	X		WD	
R-18												X	
R-19												WD	
R-20												WD	
	197+43S		PL-24	19,743		X		X	X	X			
R-21												X	
R-22												WD	
R-23												WD	
R-24												X	
R-25	239+80S			23,980		X		X				WD	
R-26												WD	
R-27												X	

Table F-5. Beach-profile surveys south of Canaveral Harbor from south jetty to R-53, October 1951 to May 1975.

DEP Survey Mon. Number	USACE Canaveral Harbor Beach Profile Survey Line Number	USACE Beach-Erosion Control Profile Line No.	Distance from Harbor Channel Centerline, ft	USACE Canaveral Harbor Monitoring Surveys Month/Year of Survey				USACE BEC Survey	USACE Beach-Erosion Control Surveys		DEP CCCL Survey	USACE Trident Survey
				Oct-51	May-54	Oct-56	Nov-58	Mar-65 to Jan-66	May, Jun, Sep-71	Feb, Aug, Sep-72	Sep-72 to Nov-72	May-75
R-28											WD	
	290+14S	PL-25	29,014		X		X	X	X			
R-29											WD	
R-30											X	
R-31											WD	
R-32	**Ocean Pines**										WD	
R-33											X	
R-34											WD	
R-35											WD	
	343+98S	PL-26	34,398		X		X	X				
R-36											X	
R-37											WD	
R-38											WD	
R-39											X	
R-40											WD	
R-41											WD	
		PL-27						X				
R-42											X	
R-43											WD	
	Noro property											
R-44											WD	
R-45											X	
R-46											WD	
		PL-28						X				
R-47											WD	
R-48											X	
R-49											WD	
		PL-29						X				
R-50											WD	
R-51											X	
R-52											WD	
	508+51S	PL-30						X				
R-53											WD	
PATRICK AIR FORCE BASE												

Note: Columns with shading denote surveys that were used in the volume analysis and plotted on the plates at the end of Appendix F.

Table F-6. Beach-profile surveys south of Canaveral Harbor from south jetty to R-53, March 1979 to January 1997.

DEP Survey Mon. NO.	USACE Canaveral Harbor Beach Profile Survey Line No.	USACE Beach-Erosion Control Profile Line No.		Distance from Harbor Channel Centerline, ft	USACE Trident Mon. Surveys		USACE BEC Survey	DEP CCCL Survey	USACE BEC Survey	USACE BEC Survey	USACE Sand-Bypassing Monitoring Surveys			
					Mar-79	Dec-79	May-85 to Jun-85	Aug-85 to May-86	Sep-88	Jan-94	Feb-94 to Apr-94	Jan-95 to Feb-95	Jan-96	May-97**
				Range 400, Centerline of South Jetty										
	Rge 550			700										
R-0											X	X	X	X
	Rge 600			750										
		P-17A			X									
	Rge 800			950	X									
	CDA-B, P9	Line 9	P-17A1											
	10+OOS			1,000										
R-1					X	X	X	X	X	X	X	X	X	X
	CDA-B, P9A													
R-1AA														
	CDA-B,P10	Line 10												
	Rge 1000			1,150										
R-1A														
	15+00S			1,500										
	Rge 1200			1,350										
	Rge 1400			1,550										
	CDA-B, P10A													
		P-17B												
R-2	CDA-B, P11	Line 11			X	X	WD	WD	X	WD	X	X	X	X
	20+00S			2,000										
	CDA-B,P11A													
	CDA-B, P12	Line 12			X									
	25+00S	P-18 Alt	PL-18	2,500	X									
	CDA-B, P12A													
	CDA-B, P13	Line 13												
	30+00S			3,000										
R-3					X	X	X	X	X	WD	X	X	X	X
	CDA-B, P13A													
	CDA-B, P14	Line 14												
		P-18A	PL-18											
	CDA-B, P14A													
R-4					X	X	WD	WD	X	X	X	X	X	X
	40+00S			4,000										
	CDA-B, P-15	Line 15												
		P-18B												
	CDA-B, P15A													
	CDA-B, P16	Line 16												
R-5	50+00S	P-19	PL-19	5,000	X	X	WD	WD	X	WD	X	X	X	X
	CDA-B, P17	Line 17												
	CDA-B, P17A				X									
	CDA-B, P18	Line 18												
R-6	CDA-B, P18A				X	X	X	X	X	WD	X	X	X	X
	60+00S	P-19A		6,000										
	CDA-B, P19	Line 19												
	CDA-B, P19A													
	CDA-B, P20	Line 20												

Table F-6. Beach-profile surveys south of Canaveral Harbor from south jetty to R-53, March 1979 to January 1997.

DEP Survey Mon. NO.	USACE Canaveral Harbor Beach Profile Survey Line No.	USACE Beach-Erosion Control Profile Line No.		Distance from Harbor Channel Centerline, ft	USACE Trident Mon. Surveys		USACE BEC Survey	DEP CCCL Survey	USACE BEC Survey	USACE BEC Survey	USACE Sand-Bypassing Monitoring Surveys			
					Mar-79	Dec-79	May-85 to Jun-85	Aug-85 to May-86	Sep-88	Jan-94	Feb-94 to Apr-94	Jan-95 to Feb-95	Jan-96	May-97**
R-7				6,698	X	X	WD	WD	X	X	X	X	X	X
	CDA-B, P20A			**Applegate**										
		P-20B												
	75+00S		PL-20	7,500										
	CDA-B, P21	Line 21												
R-8	CDA-B, P21A				X	X	WD	WD	X	WD	X	X	X	X
	CDA-B, P21B													
	CDA-B, P21C													
			20A											
R-9	CDA-B, P22	Line 22			X	X	X	X	X	WD	X	X	X	X
	90+00S			9,000										
	CDA-B, P22A													
	CDA-B, P22B													
			20B											
R-10	CDA-B, P23	Line 23			X	X	WD	WD	X	X	X	X	X	X
	CDA-B, P23A													
	CDA-B, P23B													
	105+00S		PL-21	10,500										
R-11	**South limit of Trident Fill**				X	X	WD	WD	X	WD	X	X	X	X
	CDA-B, P24	Line 24												
	CDA-B, P24A													
	CDA-B, P24B													
	CDA-B, P24C				X	X								
R-12					X	X	X	X	X	WD	X	X	X	X
		Line 25	21A											
R-13					X		WD	WD	X	X	X	X	X	X
		Line 26												
	133+84S		PL-22	13,384										
R-14					X		WD	WD	X	WD	X	X	X	X
		Line 27												
		Line 28	22B											
R-15	**South limit of 2.8-mile project**			14,784	X		X	X	X	WD	X	X	X	X
		Line 29	22C											
R-16				15,500	X		WD	WD		X				
R-17	165+03S		PL-23	16,503			WD	WD		WD				
R-18							X	X		WD				
R-19							WD	WD		X				
R-20							WD	WD		WD				
	197+43S		PL-24	19,743										
R-21							X	X		WD				
R-22							WD	WD		X				
R-23							WD	WD		WD				
R-24							X	X		WD				
R-25	239+80S			23,980			WD	WD		X				
R-26							WD	WD		WD				
R-27							X	X		WD				
R-28							WD	WD		X				
	290+14S		PL-25	29,014										
R-29							WD	WD		WD				

Table F-6. Beach-profile surveys south of Canaveral Harbor from south jetty to R-53, March 1979 to January 1997.														
DEP Survey Mon. NO.	USACE Canaveral Harbor Beach Profile Survey Line No.	USACE Beach-Erosion Control Profile Line No.		Distance from Harbor Channel Centerline, ft	USACE Trident Mon. Surveys		USACE BEC Survey	DEP CCCL Survey	USACE BEC Survey	USACE BEC Survey	USACE Sand-Bypassing Monitoring Surveys			
					Mar-79	Dec-79	May-85 to Jun-85	Aug-85 to May-86	Sep-88	Jan-94	Feb-94 to Apr-94	Jan-95 to Feb-95	Jan-96	May-97**
R-30							X	X		WD				
R-31							WD	WD		X				
R-32	**Ocean Pines**						WD	WD		WD				
R-33							X	X		WD				
R-34							WD	WD		X				
R-35							WD	WD		WD				
	343+98S		PL-26	34,398										
R-36							X	X		WD				
R-37							WD	WD		X				
R-38							WD	WD		WD				
R-39							X	X		WD				
R-40							WD	WD		X				
R-41							WD	WD		WD				
			PL-27											
R-42							X	X		WD				
R-43							WD	WD		X				
	Noro Property													
R-44							WD	WD		WD				
R-45							X	X		WD				
R-46							WD	WD		X				
			PL-28											
R-47							WD	WD		WD				
R-48							X	X		WD				
R-49							WD	WD		X				
			PL-29											
R-50							WD	WD		WD				
R-51							X	X		WD				
R-52							WD	WD		X				
	508+51S		PL-30											
R-53							WD	WD		WD				
PATRICK AIR FORCE BASE														

Note: Columns with shading denote surveys that were used in the volume analysis and plotted on the plates at the end of Appendix F.
** The May 1996 survey column was omitted for clarity, but was included in the volume analysis.

Table F-7. Brevard County, Florida, Shore Protection Project beach-profile surveys.			
D.O. File No.	**No. of Sheets**	**Survey Dates**	**Description**
24-29, 128 Beach-Erosion Control Study	35	1928 1965 1958 Jun-71	Baseline control and beach-profile surveys, 47 lines from the north county line to just south of Sebastian Inlet.
24-31, 322 Canaveral Harbor, FL Interim Beach Nourishment for Downdrift Shore	9	May-71 to Jun-71	Baseline control and beach-profile surveys, 8 lines from 5,000 ft north to 5,000 ft south of Harbor, PL-16C, PL-17, PL-17A, PL-17B, PL-18, PL-18A, PL-18B, PL-19; logs of core borings and grain size curves.
24-31, 488 Beach-Erosion Control Project Survey Control and Layout	4	-	Survey control and layout for survey in D.O. File 24-32, 002.
24-31, 727 Beach-Erosion Control Study Profile Lines	1	1958 May-65 Jun-71 Sep-73	Beach-profile survey comparisons for Profile Lines 20, 21, 22, 23. Sep-71 offshore profiles limited to between -12 and -15 ft.
24-31, 847 Canaveral Monitoring Surveys	4	Sep-71 Feb-72 Aug-73 Dec-73 Jul-74	Beach-profile survey comparisons for Profile Lines P-17, Cut 2, PL-17A, PL-17A-1, PL-17B, PL-18Alt, PL-18A. Many surveys are limited to wading depth.
24-31, 849 Canaveral Nourishment Study	11	Feb-72 Aug-72 Sep-72	Beach-profile surveys, 29 lines taken in area from 5,000 ft north to 14,800 ft south of Harbor, PL-1 to PL-29.
24-31, 851 Canaveral Harbor, FL Pre-dredging Survey for Interim Beach Nourishment	5	Mar-72	Sta. -4+00 to Sta. 23+00, 28 profile lines. Surveys extend to -12 ft.
24-31, 990 Canaveral Monitoring Surveys	1-6 of 23	Jul-74 Aug-74 Nov-74	Survey control and layout, beach-profile cross sections for 9 lines, P-17, Cut 2, PL-8, PL-17A, PL-17A-1, PL-17B, PL-18Alt, PL-18A, PL-19A.
	7-11 of 23	Jan-75 Feb-75 May-75	Beach-profile surveys for 9 lines, P-17, Cut 2, PL-8, PL-17A, PL-17A-1, PL-17B, PL-18Alt, PL-18A, PL-19A.
	12-23 of 23	Jan-75 Feb-75 May-75	Beach-profile surveys for 26 lines for the Trident beach disposal area (CDA-B series beach-profile lines).
24-31, 998 1965 Beach-Erosion Control Study Update	4	1928 1965 Nov-74	Five 1965 profile lines (30, 31, 32, 33, and 34) were resurveyed in Nov-74. The lines are located in or near Patrick AFB. The Nov-74 offshore survey is limited to -10 ft.
24-32, 002 Beach-Erosion Control Project Exam Survey	7	May-71 to Jun-71	Survey for the G&DDM dated Sep-72. 17 profile lines were taken over the 2.8-mile Canaveral project segment. 16 profile lines were taken over the 2-mile Indialantic and Melbourne Beach project segment.
24-32, 608 Beach-Erosion Control Project G&DDM Addendum	7	1928 1965 May-71 1972 Sep-77	Comparative beach-profile surveys. Surveys extend to -20 to -25 ft. Profile Lines PL-38, PL-39, PL-40, PL-41, R-120, R-123, R-126, R-129, R-132, R-135, R-138 survey in the area of 2-mile Indialantic and Melbourne Beach project segment
24-32, 851 Indialantic and Melbourne Beach Plans and Specifications	24	-	P&S sheets, file is dated Sep-78. These sheets are missing from the D.O. File drawer.

Table F-7. Brevard County, Florida, Shore Protection Project beach-profile surveys.			
D.O. File No.	No. of Sheets	Survey Dates	Description
24-33, 100 Beach-Erosion Control Project Comparative Profiles, Canaveral Harbor Sections	6	May-75 Mar-79	Mar-79 beach-profile lines extend to -20 to -25 ft. 23 profile lines were surveyed and extend from the south jetty to R-16.
24-33, 759 Indialantic and Melbourne Beach Plans and Specifications As-Builts	-	-	P&S sheets, file is dated Sep-81. These sheets are missing from the D.O. File drawer.
24-33, 776 Indialantic and Melbourne Beach Comparative Profiles	10	Sep-81	Survey control and beach-profile surveys. 27 lines were surveyed from R-122+451 to R-127.
24-33, 824 Canaveral Harbor Sections Comparative Profiles	6	Mar-79 Dec-79	Comparative beach-profile cross sections for R-1 through R-12. Profiles extend to -25 ft.
24-34, 594 Beach-Erosion Comparative Profiles	34	May-85 to Jun-85	R-1, R-3, R-6,,,R-219 surveyed to -25-ft contour. R-2, R-4, R-7, R-8, R-10, R-11, R-13, R-14, R-16, and R-17 were surveyed to wading depth only.
24-35, 379 City of Canaveral Monitoring Survey	12	Sep-88	R-1 through R-15 surveyed. Profiles extend to -15 to -20 ft.
24-36, 564 Shore Protection Project Feasibility Survey Beach Profiles	29	Dec-93	R-1, R-4, R-7, R-10...R-52 were surveyed to -20 ft. R-2, R-3, R-5, R-6...R-51 were surveyed to wading depth. R-56, R-59, R-62, R-65, R-68, R-71, and R-74 at Patrick AFB were surveyed to wading depth. R-76, R-79, R-81...R-136 were surveyed to -20 ft. R-77, R-78, R-80, R-81, R-83, R-84...R-137 were surveyed to wading depth.
24-37, 570 Brevard County, FL, Shore Protection Project Plans and Specifications Surveys, North Reach	23	Nov-97 to Feb-98	Profile Lines R-1 through R-53, and intermediate lines at 500-ft intervals.
24-37, 565 Brevard County, FL, Shore Protection Project Plans and Specifications Surveys, South Reach	10	Dec-97 to Jan-98	Profile Lines R-117 through R-139, and intermediate lines at 500-ft intervals.

From May to June 1971, beach profiles used in the USACE G&DDM dated September 1972 were surveyed. Seventeen profile lines were taken along the 2.8-mile Canaveral Beach project segment. Sixteen profile lines were taken along the 2.0-mile Indialantic and Melbourne Beach Project segment. In March 1979, the USACE surveyed FDEP Beach Profiles R-1 to R-16. The March 1979 data extends to between the -20 to -25-ft contour. FDEP Profile Lines R-1 through R-12 were resurveyed by the USACE in December 1979. The December 1979 data extends to the -25-ft contour. In September 1981, 27 profile lines between R-122+451 to R-127 were surveyed by the USACE.

The USACE surveyed R-1, R-3, R-6, R-9...R-219 to the 30-ft contour, and R-2, R-4, R-5, R-7, R-8...R-218 to wading depth in May and June 1985. In September 1988, the USACE resurveyed R-1 through R-15. The 1988 survey extended offshore to the -15 to -20-ft contour. In January 1994, the USACE completed a survey of every third FDEP beach profile in Brevard County from the south jetty to the south county line, excluding Patrick AFB. The beach-profile

surveys for the contract plans for the Brevard County shore protection project were taken from November 1997 through February 1998.

F.5.4. FDEP Surveys

The FDEP establishes CCCLs on a countywide basis. Surveys of the beach and offshore areas are an integral part of studies performed by the FDEP for its control line program. The FDEP surveyed R-1, R-3, R-6, R-9,..R-219 to the 30-ft depth contour and R-2, R-4, R-6, R-7, R-8, ... R-218 to wading depth for the purpose of establishing a CCCL for Brevard County in September through November 1972. FDEP resurveyed the same profile lines for reestablishment of the CCCL in Brevard County from August 1985 to May 1986. Because the State does not establish CCCLs for Federal property, the Brevard County CCCL does not extend north of Canaveral Harbor. The FDEP has also performed ten post-storm or conditional surveys of the beaches in Brevard County since 1972. Post-storm and condition surveys do not extend seaward beyond wading depth (-5 ft MLW) and are taken for a limited number of profile lines. Table F-8 lists the FDEP surveys, including the number of offshore and onshore profiles, the total number of points (elevation data) taken, the survey type, and survey dates.

Table F-8. Brevard County, Florida, beach-profile survey inventory from the FDEP.

Survey Dates	Number of Offshore Profiles	Number of Onshore Profiles	Total Number of Points	Survey Type
Sep to Nov-72	74	219	4,807	Control Line
Nov-73	0	32	361	Post Storm
Oct-74	0	59	723	Post Storm
Oct-74	0	5	55	Post Storm
Sep-79	0	14	178	Post Storm
Nov-81	0	15	162	Post Storm
May-82	0	30	520	Post Storm
Jul-83	0	74	1,414	Condition
Feb-85	0	193	5,429	Post Storm
May to Jun-85	74	93	4,161	Special
Aug-85 to May-86	74	219	5,848	Control Line
Apr-86	0	21	391	Special
Apr-86	0	21	239	Special
May-86	0	21	177	Special
Jun-86	0	21	239	Special

F.6. Volume Computations

As noted in the earlier sections of this appendix, there is a wealth of survey data for the beaches of Brevard County. Many of the surveys were taken for limited areas, such as the condition surveys taken by FDEP, or have been taken once, such as the USACE survey in 1965-1966 for Brevard County from Cape Canaveral to the north county line. The USACE completed a survey for the area 2 miles north and south of the Harbor just prior to the pilot cut through the barrier island in October 1951. In May 1954, the USACE expanded the October 1951 survey to extend 4 miles north and 6.5 miles south of the Harbor. The 1951 and 1954 surveys serve as the basis for examining volume changes to the shores adjacent to Canaveral Harbor since its construction.

Table F-4 shows the extent of survey data north of Canaveral Harbor. Beach-profile data north of the Harbor for October 1951, May 1954, November 1958, March 1965 - January 1966, February - April 1994, January 1996, May 1996, and May 1997 were digitized for analysis. These surveys are shaded in Table F-4. Tables F-5 and F-6 show the extent of survey data from the south jetty to R-53, near the north boundary of Patrick AFB. Beach-profile data south of the Harbor for October 1951, May 1954, November 1958, March 1965 to January 1966, September to November 1972, May 1975, March 1979, December 1979, August 1985 to May 1986, January 1994, January 1996, May 1996, and May 1997 were digitized for analysis. These surveys are shaded in Tables F-5 and F-6. The location and extent of survey data from R-53 to the south county line have been compiled, but were excluded from this report since the focus is on the test Plaintiffs (test Plaintiffs are located north of R-53). Therefore, surveys south of R-53 were not listed in Tables F-5 and F-6.

Beach-profile data were digitized from the USACE D.O. map file mylar media, or obtained electronically from FDEP, in order to compare volume changes using the computer-aided design and drafting (CADD) software program. The software program MicroStation in conjunction with the support package InRoads was used to define the survey baseline data, beach-profile survey data, and conversion of data into surfaces (Digital Terrain Models (DTMs)) for each survey. Volume difference between the surfaces was then generated for each survey. The onshore limit of the volumetric analysis was the FDEP monuments. The offshore limit of the volumetric analysis is the 17-ft depth contour relative to NGVD (+1.7 ft MLW). An average-end area analysis was used to determine volume changes between each beach-profile survey line. The CADD software determined the cut, fill, and net area changes at each of the profile lines. The average net area change between adjacent long-line beach profiles was multiplied by the distance between each survey monument to define volume change.

The surveys listed above from 1951 through 1997 were digitized with CADD software. InRoads converted the digital survey data into DTMs. Much of the USACE survey data were

referenced to MLW; therefore, the elevation data were lowered -1.9 ft to convert to the NGVD 1929 reference. FDEP survey data for 1972, 1986, and USACE surveys for 1994 through 1997 were surveyed to NGVD datum and did not require elevation datum conversion.

F.6.1. Volume Analysis North of Canaveral Harbor

The pre-Harbor October 1951 survey was completed by the USACE just prior to the cut through the barrier island for the first 10,500 ft of shore north of the Harbor. The October 1951 survey was compared with the May 1954, December 1958, March 1965 to January 1966, February to April 1994, January 1996, May 1996, and May 1997 surveys to determine volume changes. The computed volume changes are listed in Table F-9. The volume changes were computed for the beach profile from the landward limit of the survey data seaward to the -17-ft contour of the October 1951 survey. The 1994 through 1997 survey data were extended landward to the limit of the October 1951 profile data in order to perform the volume comparisons. Some of the available survey data (Table F-4) were not included in the volume computations, such as the October 1956 and January, June, and October 1995 surveys, as there were sufficient surveys for comparison purposes for these time frames. Other surveys (refer to Tables F-3 and F-7) were excluded from the volume analysis because of their limited lineal extent.

The May 1954 survey repeated and expanded the October 1951 survey. The May 1954 coverage extends from 210+00N to 343+98S. The Harbor impact was fairly limited in 1954 as evidenced by volume changes to the -17-ft contour for 10,500 ft of shore north and south of the Harbor of +286,800 and -148,600 cy, respectively (refer to Tables F-9 and F-12). Therefore, the May 1954 survey is better suited as the baseline for pre-project conditions since its lineal extent is twice as great north of the Harbor, and three times longer south of the Harbor as compared with the October 1951 survey. Therefore, volume changes were also computed using the May 1954 survey as a pre-Harbor survey. The May 1954 survey was compared with the November 1958, March 1965 to January 1966, January 1996, May 1996, and May 1997 surveys for the first 13,500 ft of shore north of the Harbor. The computed volume changes are listed in Table F-10. The volume changes were computed for the beach profile from the landward limit of the survey data seaward to the -17-ft contour of the May 1954 survey. The 1994 through 1997 survey data were extended landward at the berm elevation (+8.1 ft NGVD) to the limit of the May 1954 profile data in order to perform the volume comparisons.

The May 1954 survey was compared with the November 1958 and the March 1965 to January 1966 surveys for the first 21,000 ft of shore north of the Harbor. The computed volume changes are listed in Table F-11. The volume changes were computed for the beach profile from the landward limit of the survey data seaward to the -17-ft contour of the May 1954 survey. The

1994 to 1997 survey data does not extend beyond 13,500 ft north of the Harbor, and, therefore, could not be used to compute volumes beyond 13,500 ft.

Table F-9. Volume changes north of the north jetty 10,500 ft, seaward to the -17-ft contour.

Survey Date	May-54	Nov-58	Mar-65 to Jan-66	Feb-94 to Apr-94	Jan-96	May-96	May-97
Oct-51	286,800	1,124,100	1,947,400	4,868,500	4,229,300	4,264,300	4,434,400
May-54		837,700	1,714,900	4,563,700	3,923,900	3,958,700	4,128,600
Nov-58			1,053,900	3,726,400	3,086,200	3,121,000	3,290,900
Mar-65 to Jan-66				3,534,500	2,592,900	2,953,900	3,109,400
Feb-94 to Apr-94					-639,500	-604,900	-434,700
Jan-96						35,000	205,100
May-96							170,100

Note: The 1965 data for the area north of the inlet are based on two profile lines. See Plates F-1, F-2, F-3, F-7, and F-8 for a graphical display of volume changes. The May 1954 MHW is depicted on the plates.

Table F-10. Volume changes north of the inlet 13,500 ft, seaward to the 1954 -17-ft contour.

Survey Date	Nov-58	Mar-65 to Jan-66	Feb-94 to Apr-94	Jan-96	May-96	May-97
May-54	759,900	1,445,100	6,053,400	5,468,800	5,510,300	5,732,100
Nov-58		863,200	4,689,900	4,104,000	4,145,600	4,371,800
Mar-65 to Jan-66			4,666,600	4,117,100	4,151,700	4,359,000
Feb-94 to Apr-94				-585,600	-545,100	-322,800
Jan-96					41,500	263,300
May-96						221,800

Table F-11. Volume changes north of the inlet 21,000 ft, seaward to the 1954 -17-ft contour.

Survey Date	Nov-58	Mar-65 to Jan-66
May-54	1,312,900	2,594,700
Nov-58		1,549,900
Jan-66		

Note: The 1965 data for the area north of the inlet are based on three profile lines. See Plates F-1 to F-9 for a graphical display of volume changes. The 1954 MHW line is noted on the Plates.

F.6.2. Volume Analysis South of Canaveral Harbor

The pre-Harbor, October 1951 survey was completed by the USACE just prior to the cut through the barrier island for the first 10,500 ft of shore south of the Harbor. The October 1951 survey was compared with the May 1954, December 1958, March 1965 to January 1966, May 1975, March and December 1979, August 1985 to May 1986, January 1994, January and May 1996, and May 1997 surveys to determine volume changes. These volume changes were computed for the beach profile from the landward limit of the survey data seaward to the -17-ft contour of the October 1951 survey and are listed in Table F-12. Similarly, volume changes were computed for the beach profile from the landward limit of the survey data seaward to the October 1951 MHWL (Table F-13). Some of the available survey data (see Tables F-4, F-5 and F-6) were not included in the volume computations (such as the October 1956 and the January, June, and October 1995 surveys), as there were sufficient surveys for comparison purposes for these time frames. Other surveys (refer to Tables F-3 and F-7) were excluded from the volume analysis because of their limited lineal extent.

The May 1954 survey repeated and expanded the October 1951 survey. The May 1954 coverage extends from 210+00N to 343+98S. The Harbor impact was fairly limited in 1954 as evidenced by volume changes to the -17-ft contour for 10,500 ft of shore north and south of the Harbor of +286,800 and -148,600 cy, respectively (refer to Tables F-9 and F-12). Therefore, the May 1954 survey is better suited as the baseline for pre-project conditions since its lineal extent is twice as great north of the Harbor and three times longer south of the Harbor as compared with the October 1951 survey and is more suitable as a pre-Harbor survey.

The May 1954 survey was compared with the December 1958, March 1965 to January 1966, May 1975, March and December 1979, August 1985 to May 1986, January 1994, January and May 1996, and May 1997 surveys for the shore 34,398 ft (6.5 miles) south of the Harbor. Volume changes were computed for the beach profile from the landward limit of the survey data seaward to the -17-ft contour of the May 1954 survey, (Table F-14). Similarly, volume changes were computed from the landward limit of the survey data seaward to the May 1954 MHWL and the results displayed in Table F-15 and shown on Plates F-1 through F-8. Since the May 1975, March and December 1979, January and May 1996, and May 1997 surveys only extend to 2.8 miles south of the Harbor, they could not be used to compute volumes for 6.5 miles of shore.

Table F-12. Volume changes south of the Inlet 2,500 to 10,500 ft, seaward to the -17-ft contour.

	May-54	Nov-58	Mar-65 to Jan-66	May-75	Mar-79	Dec-79	Aug-85 to May-86	Jan-94	Jan-96	May-96	May-97
Oct-51	-148,600	-494,100	-999,100	1,140,300	793,100	126,800	-109,600	-808,700	-618,800	-581,000	-701,600
May-54		-345,500	-853,900	1,284,100	931,500	1,407,700	35,500	-632,800	-470,400	-433,400	-553,300
Nov-58			-509,400	1,628,700	1,277,800	1,753,100	380,000	-325,800	-125,200	-88,600	-208,100
Mar-65 to Jan-66				2,129,800	1,777,500	2,252,300	889,400	185,500	379,600	416,400	297,700
Sep-72 Nov-72				-	-	-	-	-	-	-	-
May-75					-342,700	121,440	-1,252,300	-1,947,300	-1,751,100	-1,722,100	-1,845,300
Mar-79						465,700	-895,500	-1,597,800	-1,390,400	-1,363,800	-1,490,500
Dec-79							-1,372,500	-2,072,500	-1,872,200	-1,839,500	-1,966,900
Aug-85 to May-86								-703,160	-505,100	-468,000	-589,200
Jan-94									204,800	232,100	108,100
Jan-96										34,500	-84,300
May-96											-123,000
May-97											

Note: See Plates F-1 through F-7 for graphical display of volume changes. The May 1954 MHWL is noted on the Plates. The hydrographic data for the 1972 FDEP survey were omitted in this analysis because of irregularities in the offshore portions of the data set.

Table F-13. Volume changes south of the inlet 2,500 to 10,500 ft, seaward to the 1951 MHW.

	May-54	Nov-58	Mar-65 to Jan-66	Sep-72 to Nov-72	May-75	Mar-79	Dec-79	Aug-85 to May-86	Jan-94	Jan-96	May-96	May-97
Oct-51	-19,900	-71,700	-190,200	-361,000	117,600	66,000	74,500	-163,600	-305,200	-332,900	-295,100	-261,600
May-54		-51,900	-170,700	-341,400	132,700	75,800	89,700	-144,100	-296,500	-313,100	-276,200	-241,900
Nov-58			-119,000	-290,300	183,700	128,500	141,400	-92,400	-245,000	-261,600	-224,900	-190,300
Mar-65 to Jan-66				-171,700	298,300	240,800	256,300	26,600	-125,900	-143,000	-106,800	-71,700
Sep-72 to Nov-72					479,400	411,500	432,300	197,681	48,200	29,900	68,700	100,500
May-75						-46,300	-33,500	-281,400	-420,900	-442,700	-413,600	-382,600
Mar-79							16,323	-220,300	-367,100	-377,400	-350,900	-323,500
Dec-79								-234,900	-379,500	-396,900	-368,800	-337,600
Aug-85 to May-86									-147,700	-167,300	-130,300	-97,400
Jan-94										12,900	13,900	44,400
Jan-96											34,900	69,800
May-96												31,100
May-97												

Note: See Plates F-1 through F-7 for graphical display of volume changes. The May 1954 MHWL is noted on the Plates. The hydrographic data for the 1972 FDEP survey were omitted in this analysis because of irregularities in the offshore portions of the data set.

Table F-14. Volume changes south of the inlet from 2,500 to 34,400 ft, seaward to the -17-ft contour.					
	Nov-58	Mar-65 to Jan-66	Sep-72 to Nov-72	Aug-85 to May-86	Jan-94
May-54	-1,687,500	-1,497,700	-	-250,600	-1,304,400
Nov-58		190,100	-	1,437,300	386,400
Mar-65 to Jan-66			-	1,247,100	196,800
Sep-72 to Nov-72				-	-
Aug-85 to May-86					-1,050,300
Jan-94					

Note: See Plates F-1 through F-7 for graphical display of volume changes. The May 1954 MHW line is noted on the Plates. The hydrographic data for the 1972 FDEP survey were omitted in this analysis because of irregularities in the offshore portions of the data set.

Table F-15. Volume changes south of the inlet from 2,500 to 34,400 ft, seaward to the 1954 MHW.					
	Nov-58	Mar-65 to Jan-66	Sep-72 to Nov-72	Aug-85 to May-86	Jan-94
May-54	-574,000	-193,100	-932,800	-481,600	-496,600
Nov-58		381,200	-357,700	92,800	80,700
Mar-65 to Jan-66			-739,700	-288,500	-300,000
Sep-72 to Nov-72				451,100	438,700
Aug-85 to May-86					-11,500
Jan-94					

Note: See Plates F-1 through F-7 for graphical display of volume changes. The May 1954 MHW line is noted on the Plates.

F.7. Plaintiffs' Claims of Volume Loss

A comparison has been made of the USACE October 1951 Canaveral Harbor pre-construction survey (D.O. File 11-20, 193; three sheets, a copy of which is in Plaintiffs' possession) and the USACE January 1994 beach-profile surveys (1996 Feasibility report). The 1951 survey coverage was limited to 10,500 ft south of the south jetty. The volume difference in cubic yards was computed between the two surveys for the area bounded to the north by the inlet to a point 10,500 ft south of the inlet, to the minimum landward extent of the surveys and seaward to the October 1951 MHW shoreline (elevation +1.7 ft NGVD). The total volume change for this shore was 305,200 cy of erosion from 1951 to 1994 above and landward of the October 1951 MHW (see Table F-13).

F.7.1. Plaintiffs' First Claim of Volume Loss

In 1995, plaintiffs claimed total volumetric losses of 4.8 Mcy (claimed dune loss of 1.8 Mcy[36] and other volumetric loss of 3.0 Mcy[37]) for the first 10,500 ft south of the south jetty at Canaveral Harbor for the period 1951 to 1995. These claims of volume loss, presumably above and landward of the 1951 MHWL, are 16 times higher than those estimated from beach-profile surveys for the period 1951-1994. It is important to note that within the first 10,500 ft south of Canaveral Harbor, the Defendant estimates that 43 shorefront parcels owned by Plaintiffs sums to 5,880 ft. Because Plaintiffs shorefront parcels are 5,880 ft of the first 10,500 ft, it could be expected that erosion losses would be similarly reduced from a computed total.

Alleged volume losses from the Applegate property, which is located within the 10,500 ft south of Canaveral Harbor, totaled 42,550 cy (21,340 cy of dune and bluff erosion, [36] 21,210 cy of other volumetric loss.[37] Applegate's claim of volume losses in 1995 amounts to 13.9 % of actual loss (305,200 cy), yet Applegate's property width of 100 ft is only 0.9 % of 10,500 ft.

F.7.2. Plaintiffs' Second Claim of Volume Loss

Plaintiffs provided the Defendant a second estimate of dune and bluff volume losses from the time of purchase to 1995 on or about June 28, 1996. Summing the information provided by Plaintiffs second submission for claims within 10,500 ft south of Canaveral Harbor yields 464,710 cy of alleged losses from time of purchase to 1995. This is 1.5 times the amount of erosion from 1951 to 1994 (305,200 cy) above and landward of the 1951 MHW for the 10,500 ft of shoreline south of Canaveral Harbor. It is important to note the following: (1) Defendant estimates that Plaintiffs own 43 shorefront parcels totaling 5,880 ft within the first 10,500 ft south of Canaveral Harbor. Since Plaintiffs' shorefront parcels are 5,880 ft of the first 10,500 ft, it could be expected that erosion losses would be similarly reduced from a computed total; and (2) Plaintiffs' claims are alleged to have been made from time of purchase, and yet they exceed the estimate of loss based on survey data for the period 1951 to 1994.

The volumes losses from 1965 to 1995 have been estimated to be 125,900 cy above the 1951 MHW line for the area 10,500 ft south of Canaveral Harbor (see Table F-13). These comparisons were made based on the USACE October 1951 Canaveral Harbor pre-construction survey, the USACE 1965 survey (D.O. File 24-29, 128; thirty-five sheets, a copy of which is in Plaintiffs' possession) and the USACE January 1994 survey.

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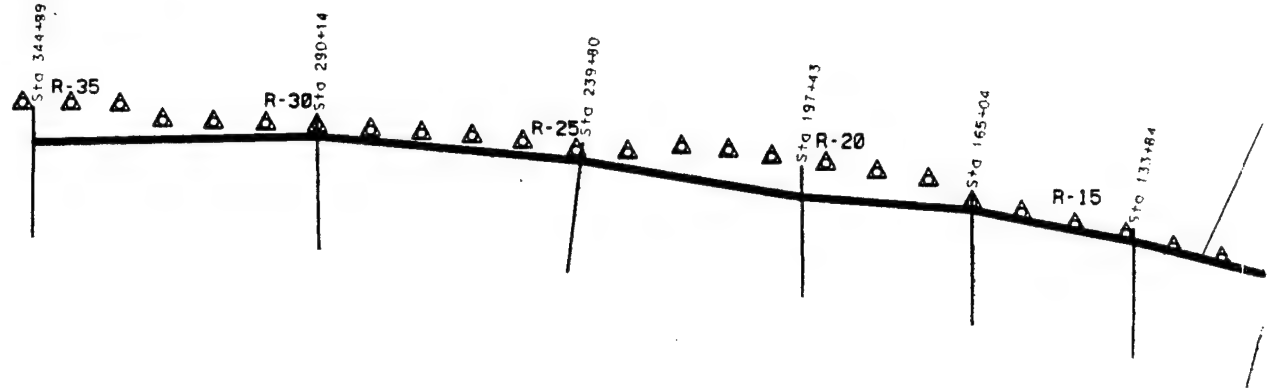
[36] Based on information in Exhibit "A," November 16, 1995, Plaintiffs' Response to Defendant's Request for Information in Accordance with Court Order Dated August 18, 1995. Volume is summed for the first 62 Plaintiffs (to R10+850).

[37] Based on information in table enclosed to 30 June 1995 Plaintiffs' Answer to Defendant's Interrogatory No. 10 and Request for Production. Volume is summed for the first 62 Plaintiffs (to R10+850).

Beside the City of Cape Canaveral (#176, 12 parcels totaling 465 ft), only two Plaintiffs (Pittman, #131, 350 ft and Eberwein, #8, 230 ft) own parcels in the first 10,500 ft of shore, and their claims of loss total 172,663 cy. Recognizing that an indefinable portion of this volume loss occurred after 1965, an estimate of Plaintiffs' volume losses after 1965 within the first 10,500 ft south of Canaveral Harbor was made by subtracting 172,663 cy from 464,710 cy. This yields 292,047 cy of alleged volume losses after 1965, which is 2.3 times the amount of erosion (125,900 cy) computed from 1965 to 1994 surveys above and landward of the 1951 MHW.

F.7.3. Other Issues Related to Plaintiffs' Volume Claims

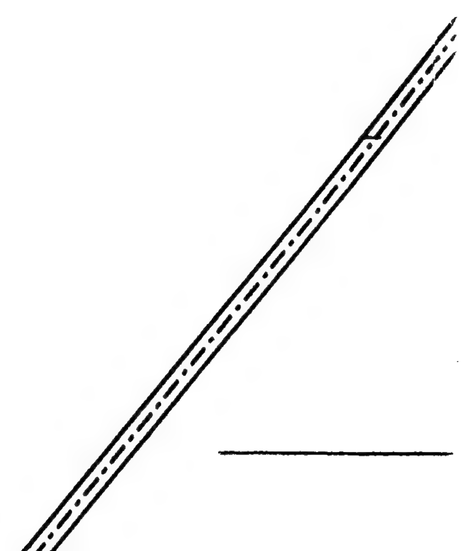
Names of plaintiffs and associated frontage (in ft) were provided to the Defendant in 1995. Summing this frontage for the first 10,500 ft south of Canaveral Harbor yields a total of 11,845 ft of ocean frontage (for Plaintiffs north of R10+850), a physical impossibility. Defendant estimates that Plaintiffs own 43 shorefront parcels totaling only 5,880 ft of ocean frontage in the first 10,500 ft south of Canaveral Harbor. This appears in large part to be duplication by Plaintiffs for condominium properties. As an example, Canaveral Sands Condominium Association (Plaintiff No. 5) claims 700 ft of frontage and 149,380 cy of dune and bluff loss, yet three additional Plaintiffs (Nos. 242, 108, and 130) appear to be claiming the same frontage and a portion of the dune and bluff loss claimed by Plaintiff No. 5. Similar discrepancies exist in Plaintiffs' Answer to Defendant's Interrogatory No. 10 and Request for Production dated June 30, 1995, and Plaintiffs' second estimate of dune and bluff volume losses dated June 28, 1996.

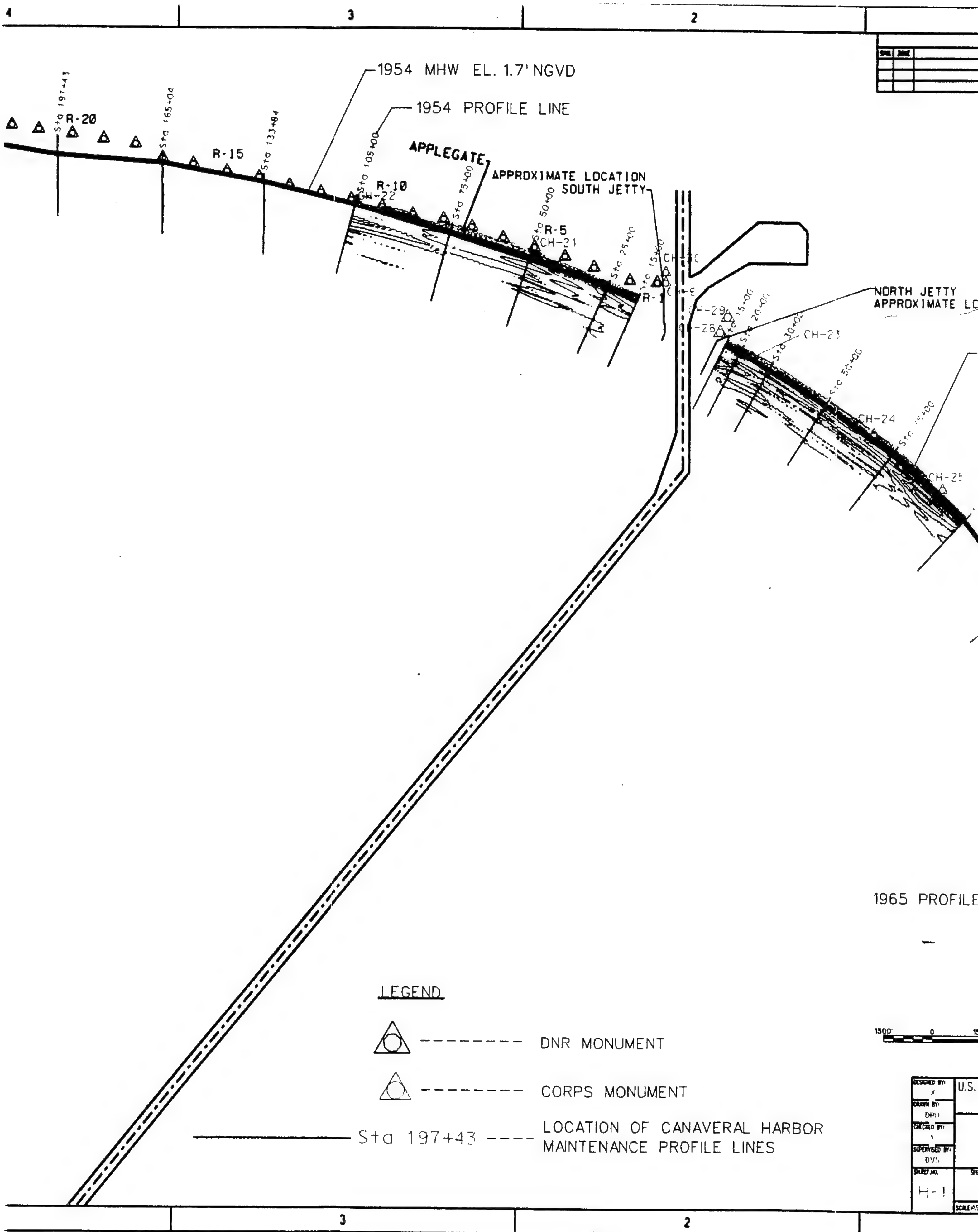


NOTES:

1. ONE FOOT CONTOUR INTERVAL.
2. VOLUMES WERE COMPUTED AS DIFFERENCES BETWEEN SURFACES GENERATED FROM EACH SURVEY.
3. VOLUME DIFFERENCES BETWEEN SURFACES WERE COMPUTED FROM LANDWARD LIMIT OF 58 SURVEY TO SEAWARD LIMIT OF THE -17 FOOT CONTOUR OF THE 1954 DATA.

————	EROSION
————	ACCRETION
————	NO CHANGE





4
3
2
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
Sta 197+43
R-20
Sta 165+04
R-15
Sta 133+84
APPLEGATE
Sta 105+00
R-10
CH-22
Sta 75+00
APPROXIMATE LOCATION
SOUTH JETTY
Sta 50+00
R-5
CH-21
Sta 25+00
Sta 15+50
NORTH JETTY
APPROXIMATE LO
CH-23
CH-24
CH-25
1965 PROFILE
LEGEND
DNR MONUMENT
CORPS MONUMENT
Sta 197+43
LOCATION OF CANAVERAL HARBOR
MAINTENANCE PROFILE LINES
1500'
0
U.S.
H-1
3
2
PL

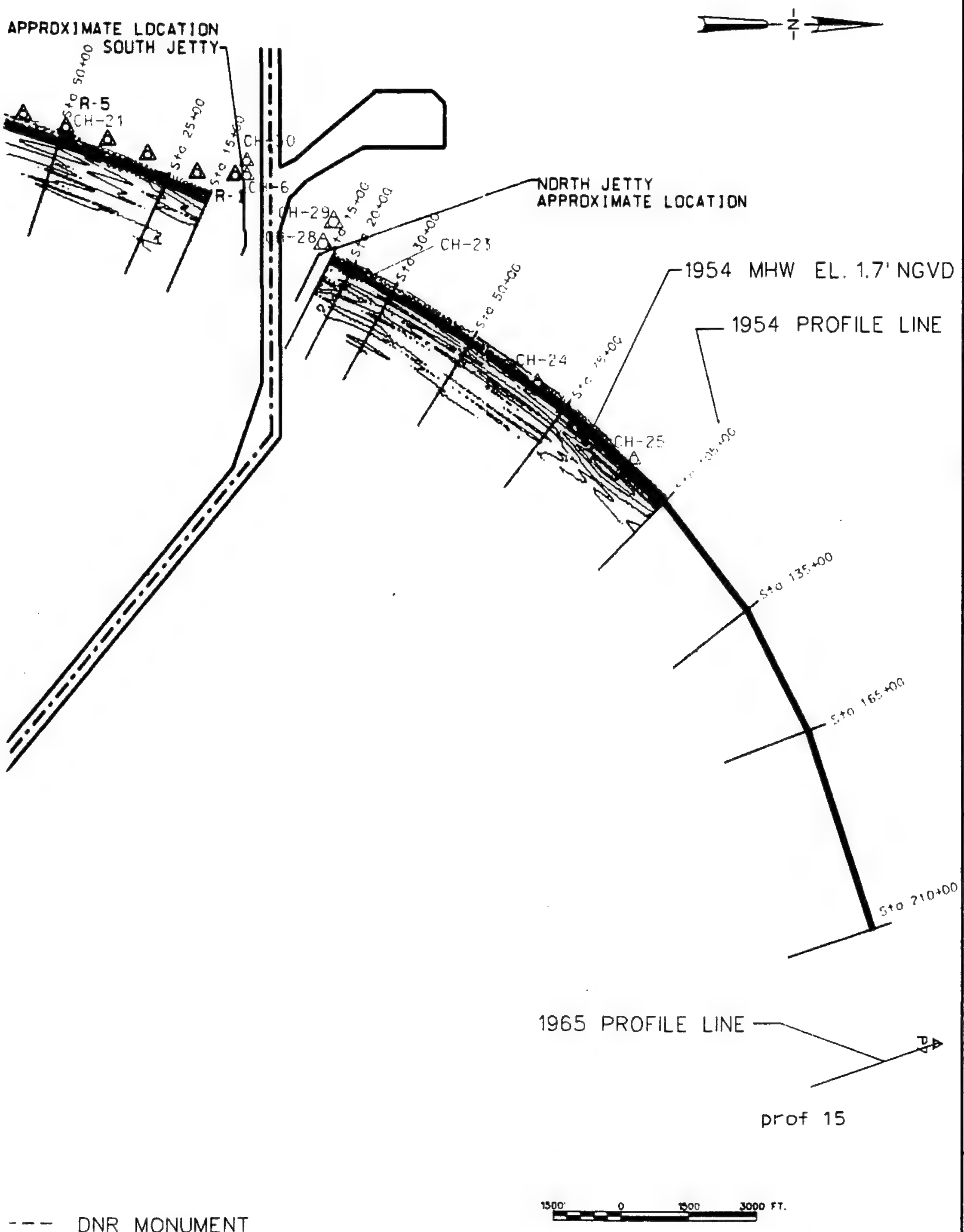
2 | 1 | U.S. ARMY

REVISIONS

SYMBOL	ZONE	DESCRIPTION	DATE	APPROVED

. 1.7' NGVD

)FILE LINE



--- DNR MONUMENT

--- CORPS MONUMENT

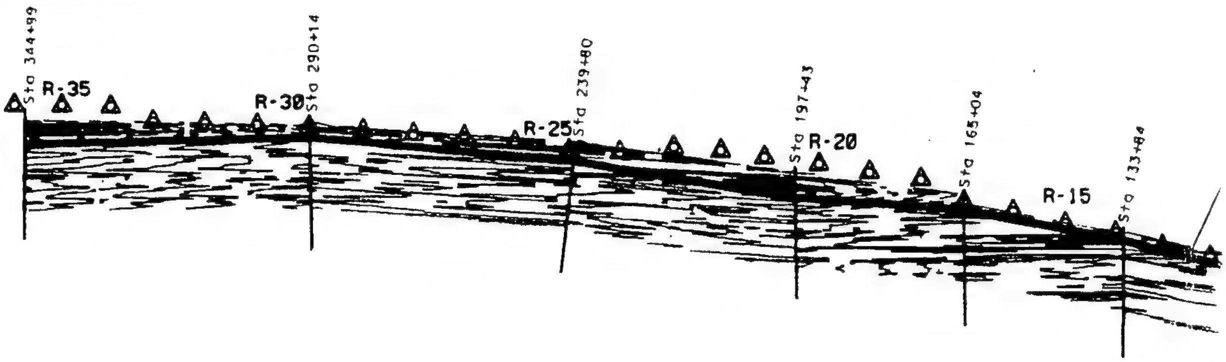
---- LOCATION OF CANAVERAL HARBOR MAINTENANCE PROFILE LINES

DESIGNED BY:	U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE CORPS OF ENGINEERS JACKSONVILLE, FL
DRAWN BY: DRH	
CHECKED BY:	BREVARD COUNTY, FLORIDA CAPE CANAVERAL VICINITY OCT 1951 - MAY 1954 DIFFERENTIAL CONTOURS
SUPERVISED BY:	
SHEET NO. H-1	SPEC NO. / CADD FILE NAME / FILE NO. / DRAWING NO.
SCALE: AS SHOWN	DATE: NOV 97 / SHEET

E D C B A

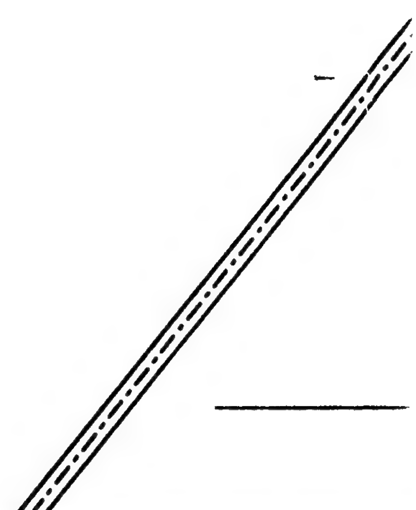
2 | 1

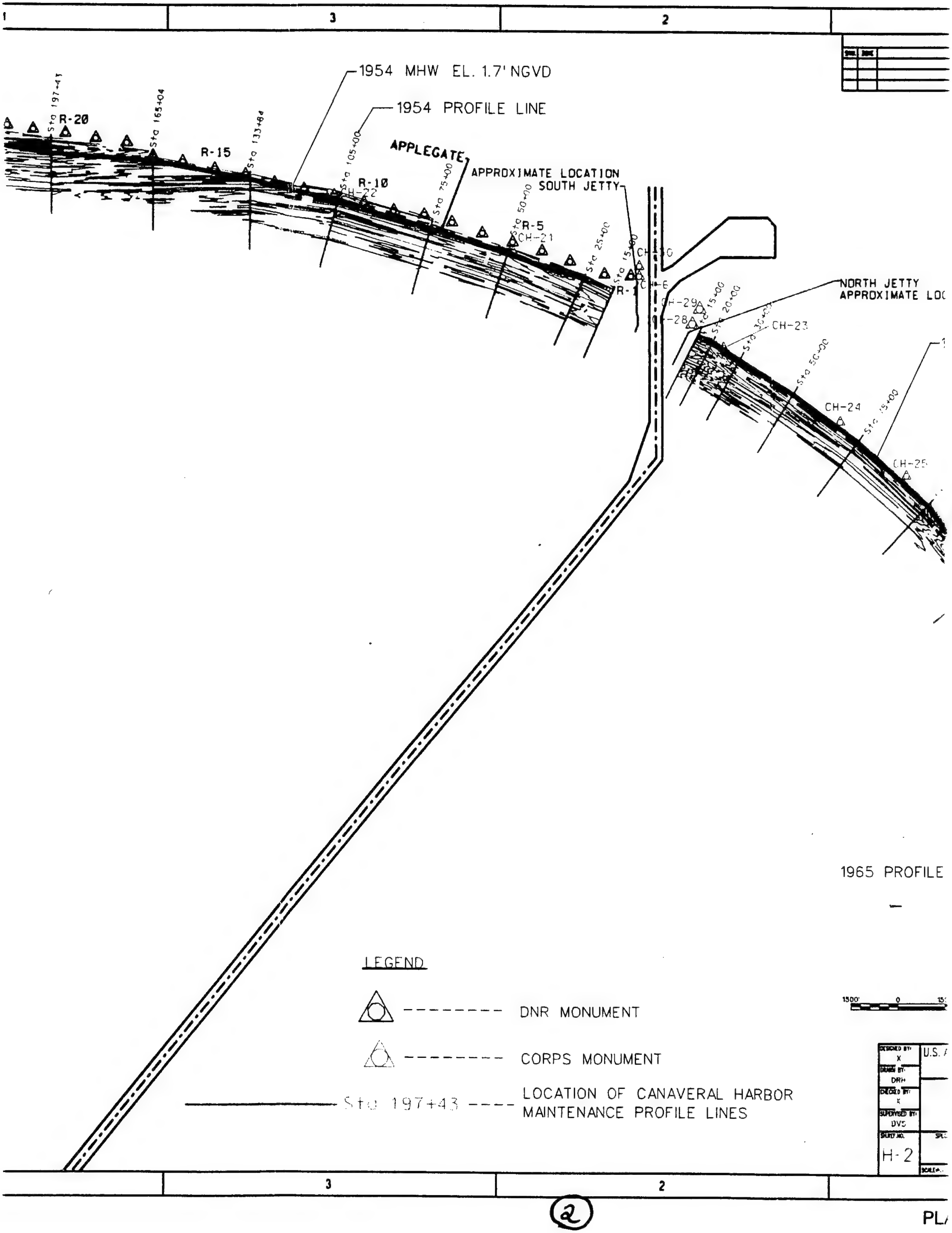
③ PLATE F-1

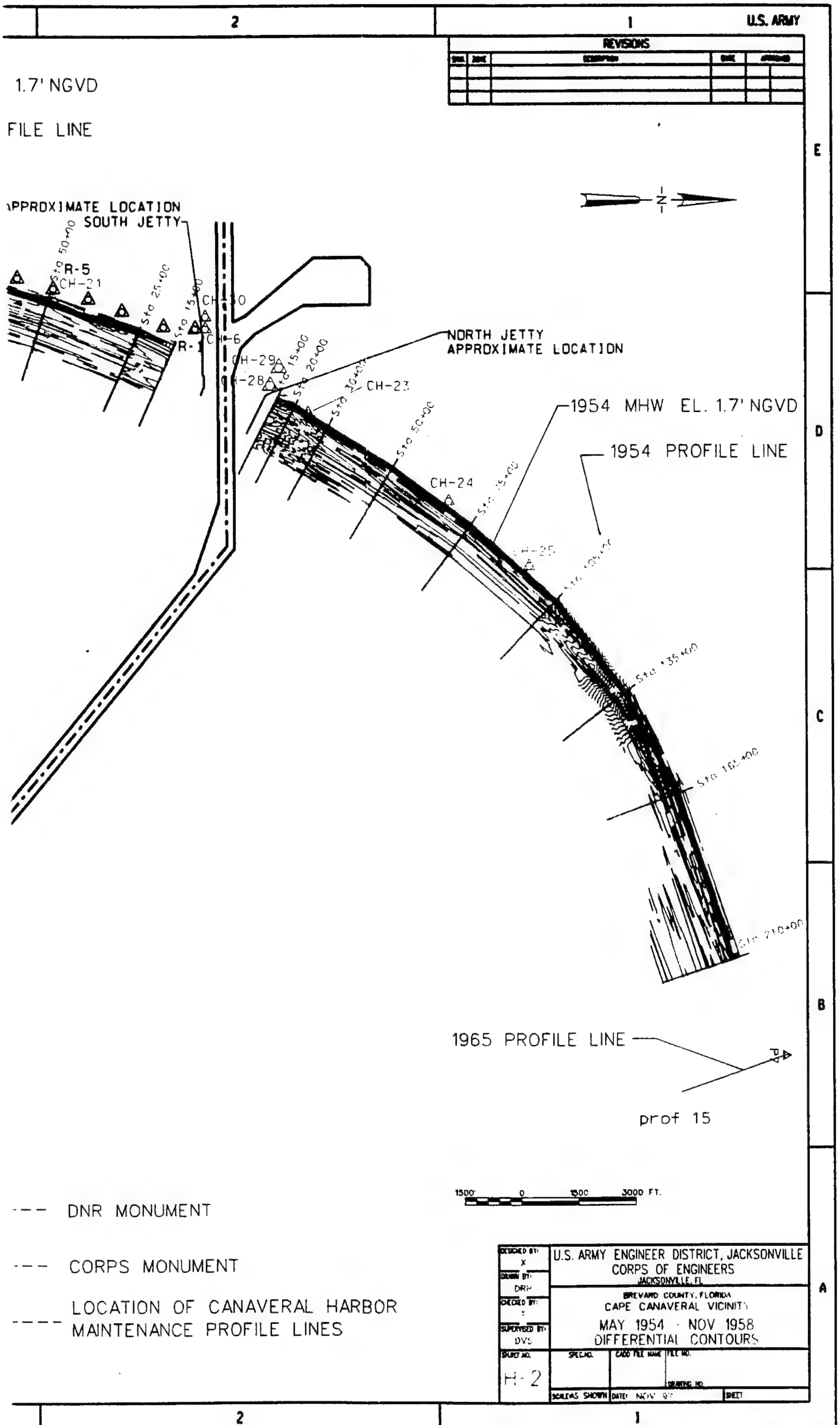


NOTES:
1. ONE FOOT CONTOUR INTERVAL.
2. VOLUMES WERE COMPUTED AS DIFFERENCES BETWEEN SURFACES GENERATED FROM EACH SURVEY.
3. VOLUME DIFFERENCES BETWEEN SURFACES WERE COMPUTED FROM LANDWARD LIMIT OF 58 SURVEY TO SEAWARD LIMIT OF THE -17 FOOT CONTOUR OF THE 1954 DATA.

———	EROSION
———	ACCRETION
———	NO CHANGE



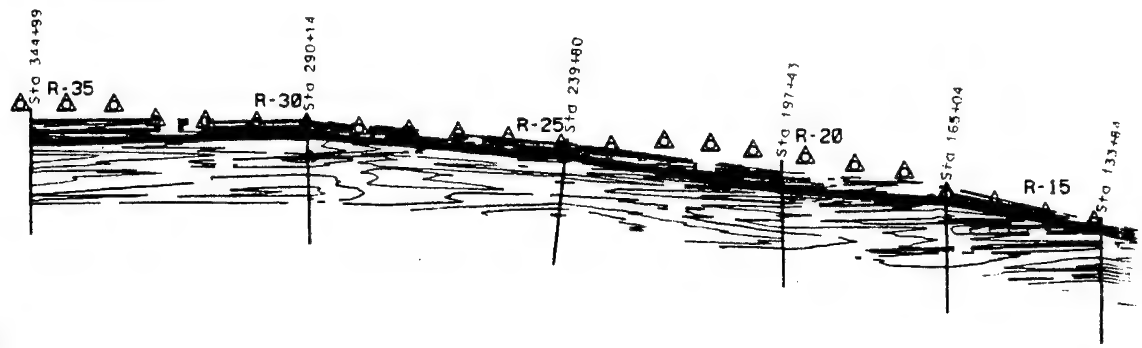

1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
APPLEGATE
APPROXIMATE LOCATION SOUTH JETTY
NORTH JETTY APPROXIMATE LOC
R-20
R-15
R-10
R-5
CH-22
CH-21
CH-23
CH-24
CH-25
Sta 197+43
Sta 165+04
Sta 133+84
Sta 105+00
Sta 75+00
Sta 50+00
Sta 25+00
Sta 15+00
Sta 20+00
Sta 50+00
Sta 75+00
1965 PROFILE
LEGEND
DNR MONUMENT
CORPS MONUMENT
Sta 197+43
LOCATION OF CANAVERAL HARBOR MAINTENANCE PROFILE LINES
U.S.
DRH
DVS
H-2
PL


U.S. ARMY
REVISIONS
1.7' NGVD
FILE LINE
APPROXIMATE LOCATION SOUTH JETTY
R-5
CH-21
CH-30
CH-6
CH-29
CH-28
CH-23
CH-24
NORTH JETTY APPROXIMATE LOCATION
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
1965 PROFILE LINE
prof 15
1500' 0 1500 3000 FT.
DNR MONUMENT
CORPS MONUMENT
LOCATION OF CANAVERAL HARBOR MAINTENANCE PROFILE LINES
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS
JACKSONVILLE, FL
BREVARD COUNTY, FLORIDA
CAPE CANAVERAL VICINITY
MAY 1954 - NOV 1958
DIFFERENTIAL CONTOURS
H-2

3 PLATE F-2

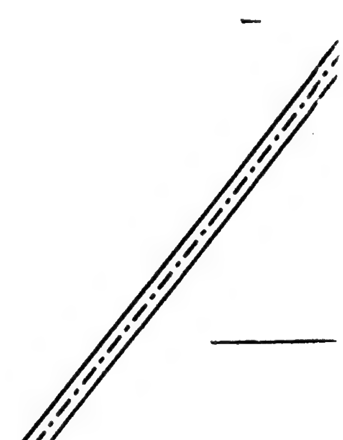
CORPS OF ENGINEERS

4



NOTES:
1. ONE FOOT CONTOUR INTERVAL.
2. VOLUMES WERE COMPUTED AS DIFFERENCES BETWEEN SURFACES GENERATED FROM EACH SURVEY.
3. VOLUME DIFFERENCES BETWEEN SURFACES WERE COMPUTED FROM LANDWARD LIMIT OF 58 SURVEY TO SEAWARD LIMIT OF THE -17 FOOT CONTOUR OF THE 1954 DATA.

————	EROSION
————	ACCRETION
————	NO CHANGE



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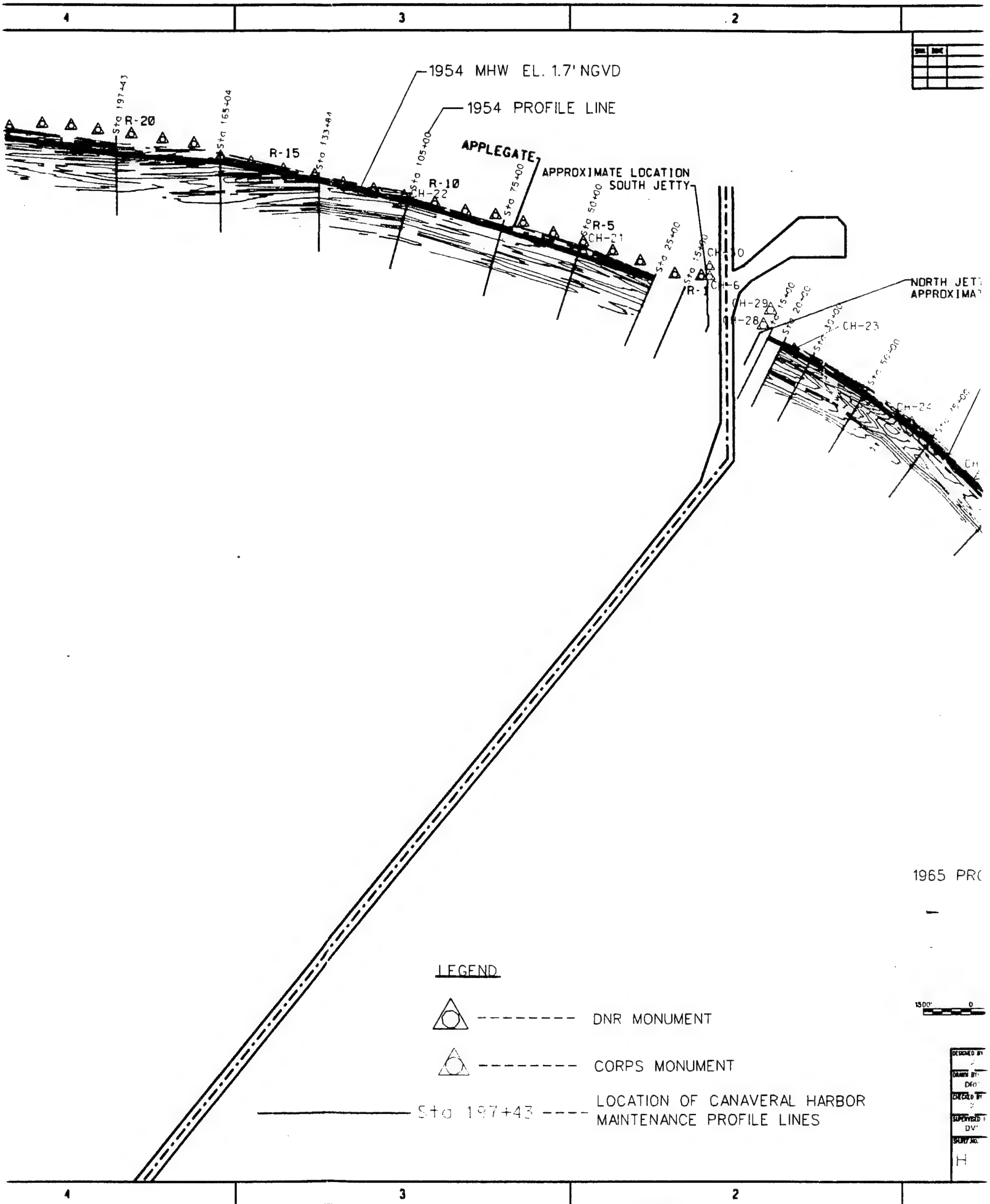
4


1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
APPLEGATE
APPROXIMATE LOCATION SOUTH JETTY
NORTH JETTY APPROXIMA
R-20
R-15
R-10
R-5
CH-22
CH-6
CH-29
CH-28
CH-23
Sta 197+43
Sta 165+04
Sta 133+84
Sta 105+00
Sta 75+00
Sta 50+00
Sta 25+00
Sta 15+00
1965 PR
LEGEND
DNR MONUMENT
CORPS MONUMENT
Sta 197+43
LOCATION OF CANAVERAL HARBOR MAINTENANCE PROFILE LINES

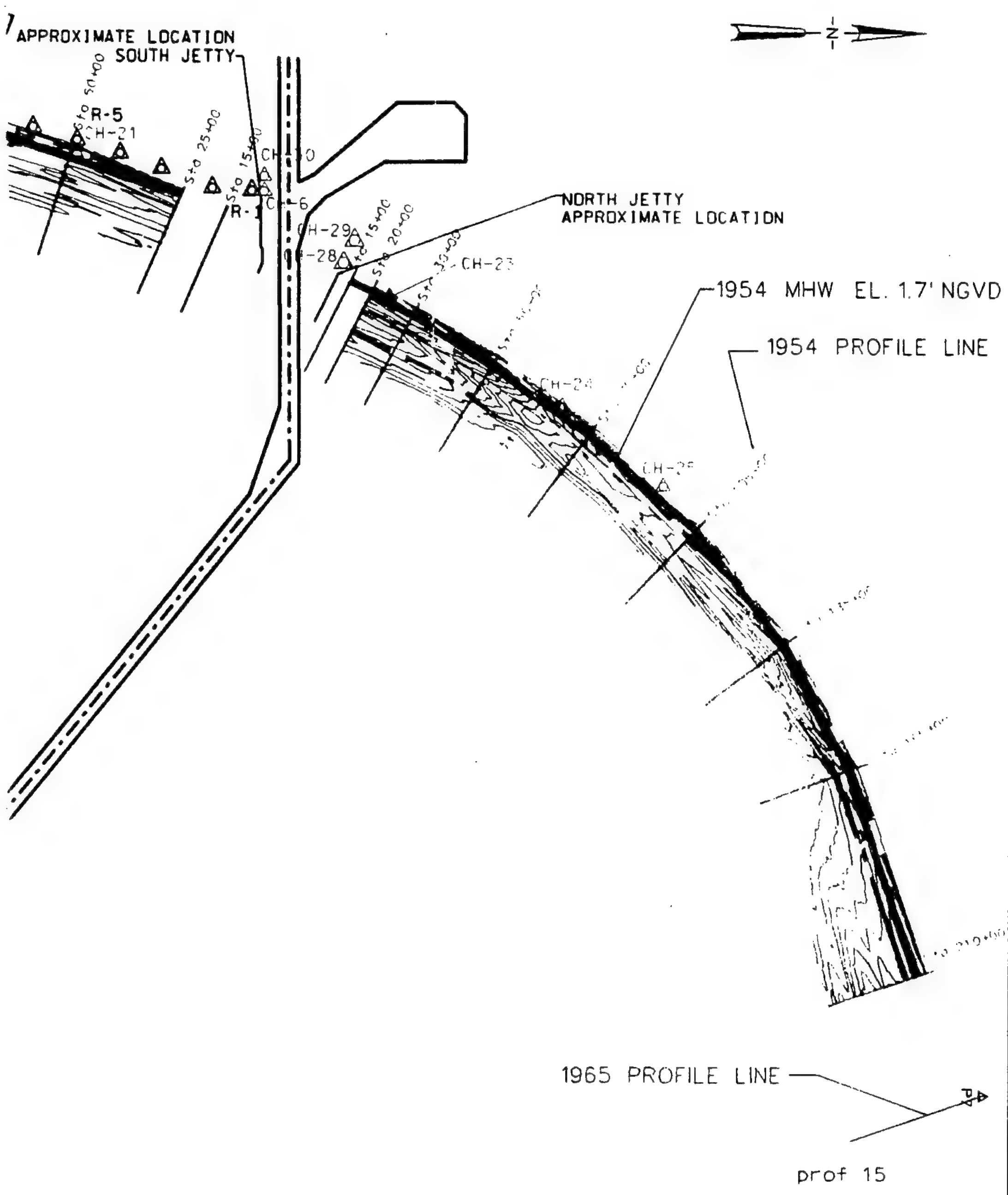
U.S. ARMY

REVISIONS

SYM.	ZONE	DESCRIPTION	DATE	APPROVED

_. 1.7' NGVD

OFILE LINE



1500' 0 1500 3000 FT.

--- DNR MONUMENT

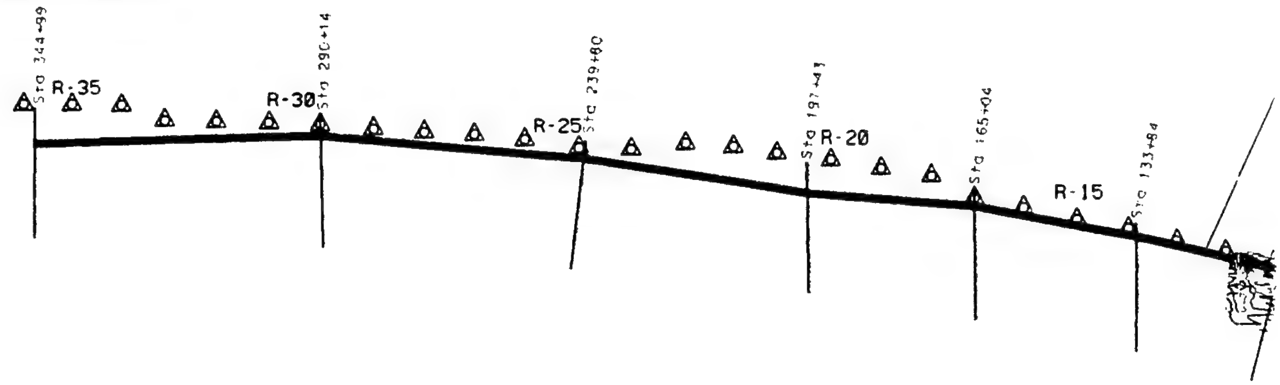
--- CORPS MONUMENT

---- LOCATION OF CANAVERAL HARBOR MAINTENANCE PROFILE LINES

DESIGNED BY:	U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE CORPS OF ENGINEERS JACKSONVILLE, FL
DRAWN BY: DRH	
CHECKED BY:	BREVARD COUNTY, FLORIDA CAPE CANAVERAL VICINITY
SUPERVISED BY: DVS	MAY 1954 - MAR 65 TO JAN 66 DIFFERENTIAL CONTOURS
SHEET NO. H 3	SPEC. NO. / CADD FILE NAME / FILE NO. / DRAWING NO.
SCALE: AS SHOWN	DATE: NOV 97 / SHEET

(3) PLATE F-3

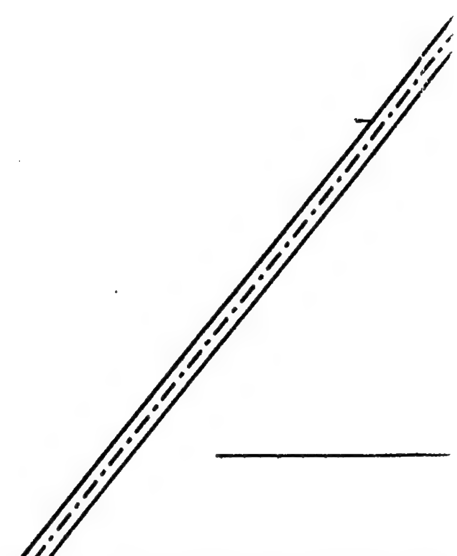
CORPS OF ENGINEERS | 4 | 3



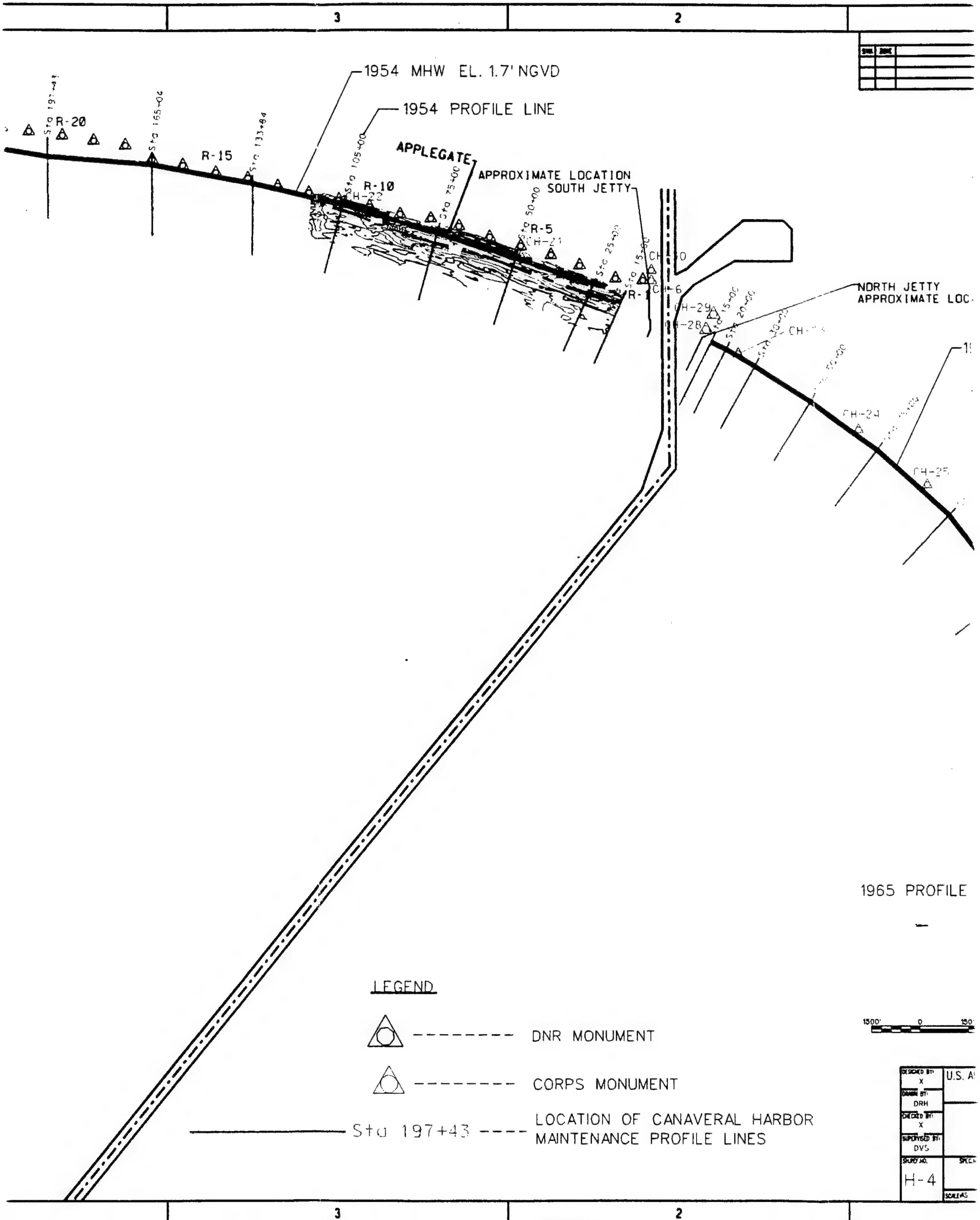
NOTES:

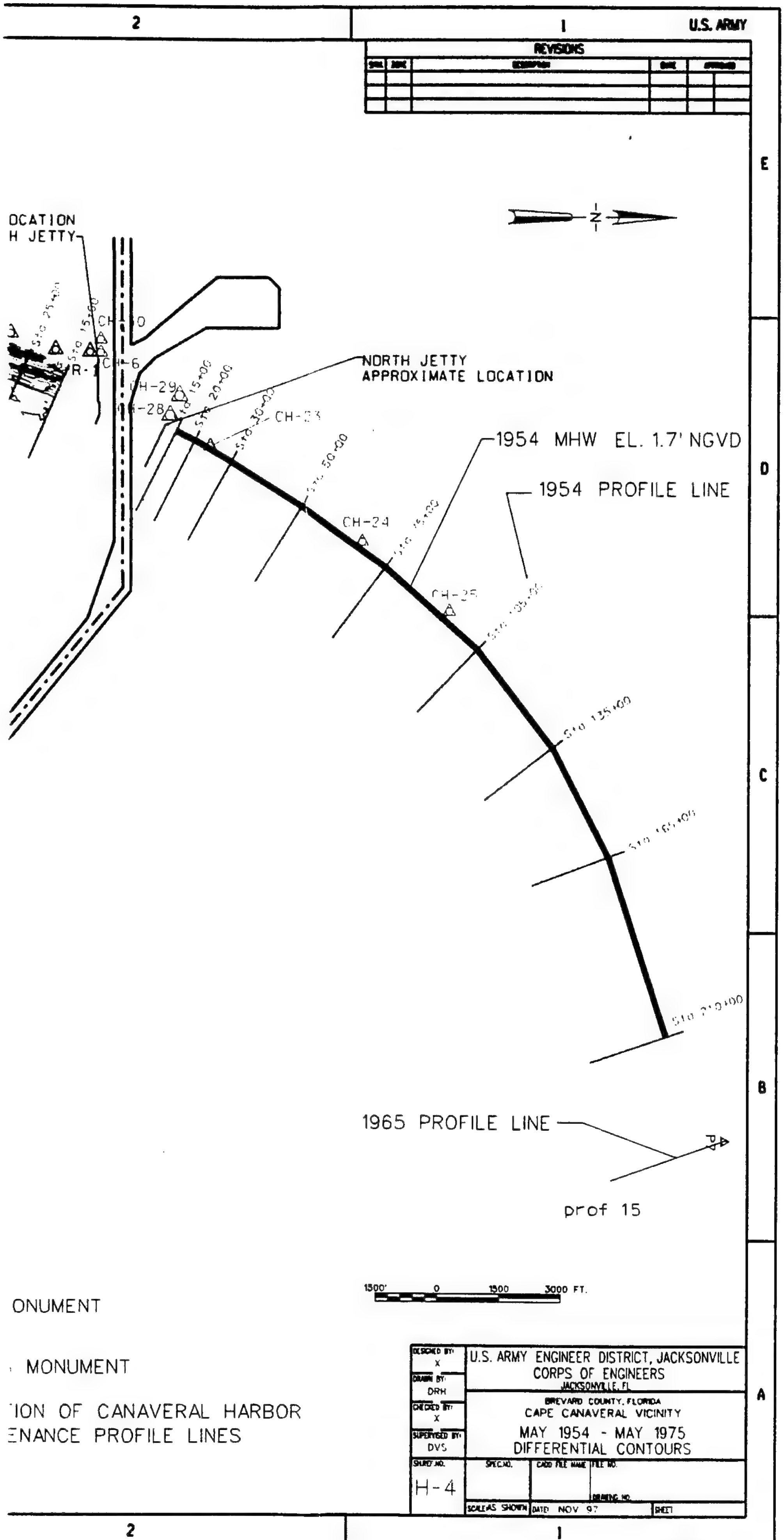
1. ONE FOOT CONTOUR INTERVAL.
2. VOLUMES WERE COMPUTED AS DIFFERENCES BETWEEN SURFACES GENERATED FROM EACH SURVEY.
3. VOLUME DIFFERENCES BETWEEN SURFACES WERE COMPUTED FROM LANDWARD LIMIT OF 58 SURVEY TO SEAWARD LIMIT OF THE -17 FOOT CONTOUR OF THE 1954 DATA.

————	EROSION
————	ACCRETION
————	NO CHANGE



5 | 4


3
2
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
APPLEGATE
APPROXIMATE LOCATION
SOUTH JETTY
NORTH JETTY
R-20
R-15
R-10
R-5
Sta 165+04
Sta 133+84
Sta 105+00
Sta 75+00
Sta 50+00
CH-29
CH-28
CH-24
1965 PROFILE
LEGEND
DNR MONUMENT
CORPS MONUMENT
Sta 197+43
LOCATION OF CANAVERAL HARBOR MAINTENANCE PROFILE LINES
DRAWN BY: DRH
CHECKED BY: X
SUPERVISED BY: DVS
H-4
3
2



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U.S. ARMY
REVISIONS
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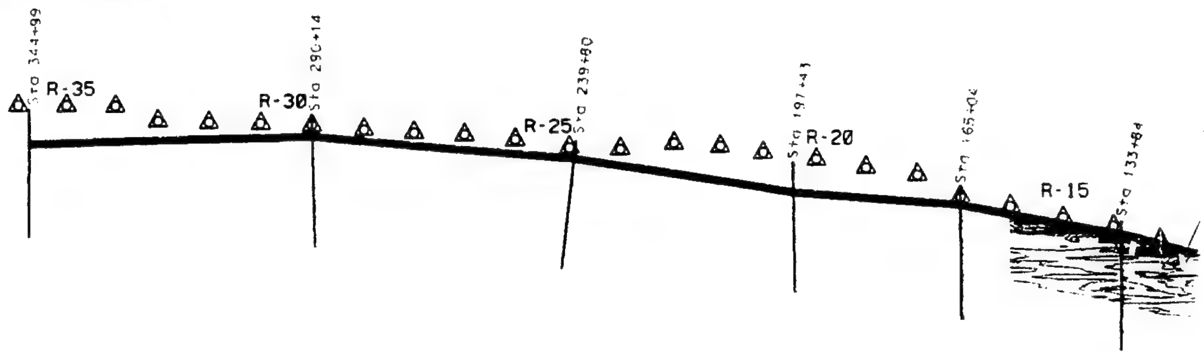
A
OCATION
H JETTY
CH-6
CH-29
CH-28
CH-23
CH-24
CH-25
NORTH JETTY
APPROXIMATE LOCATION
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
1965 PROFILE LINE
prof 15
1500' 0 1500 3000 FT.
ONUMENT
MONUMENT
ION OF CANAVERAL HARBOR
ENANCE PROFILE LINES
DESIGNED BY: X
DRAWN BY: DRH
CHECKED BY: X
SUPERVISED BY: DVS
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS
JACKSONVILLE, FL
BREVARD COUNTY, FLORIDA
CAPE CANAVERAL VICINITY
MAY 1954 - MAY 1975
DIFFERENTIAL CONTOURS
H-4
SCALE AS SHOWN
DATE NOV 97

PLATE F-4

3

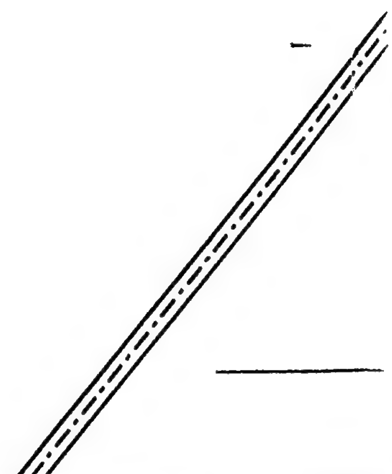
CORPS OF ENGINEERS | 4



NOTES:

1. ONE FOOT CONTOUR INTERVAL.
2. VOLUMES WERE COMPUTED AS DIFFERENCES BETWEEN SURFACES GENERATED FROM EACH SURVEY.
3. VOLUME DIFFERENCES BETWEEN SURFACES WERE COMPUTED FROM LANDWARD LIMIT OF 58 SURVEY TO SEAWARD LIMIT OF THE -17 FOOT CONTOUR OF THE 1954 DATA.

————	EROSION
————	ACCRETION
————	NO CHANGE



5 | 4

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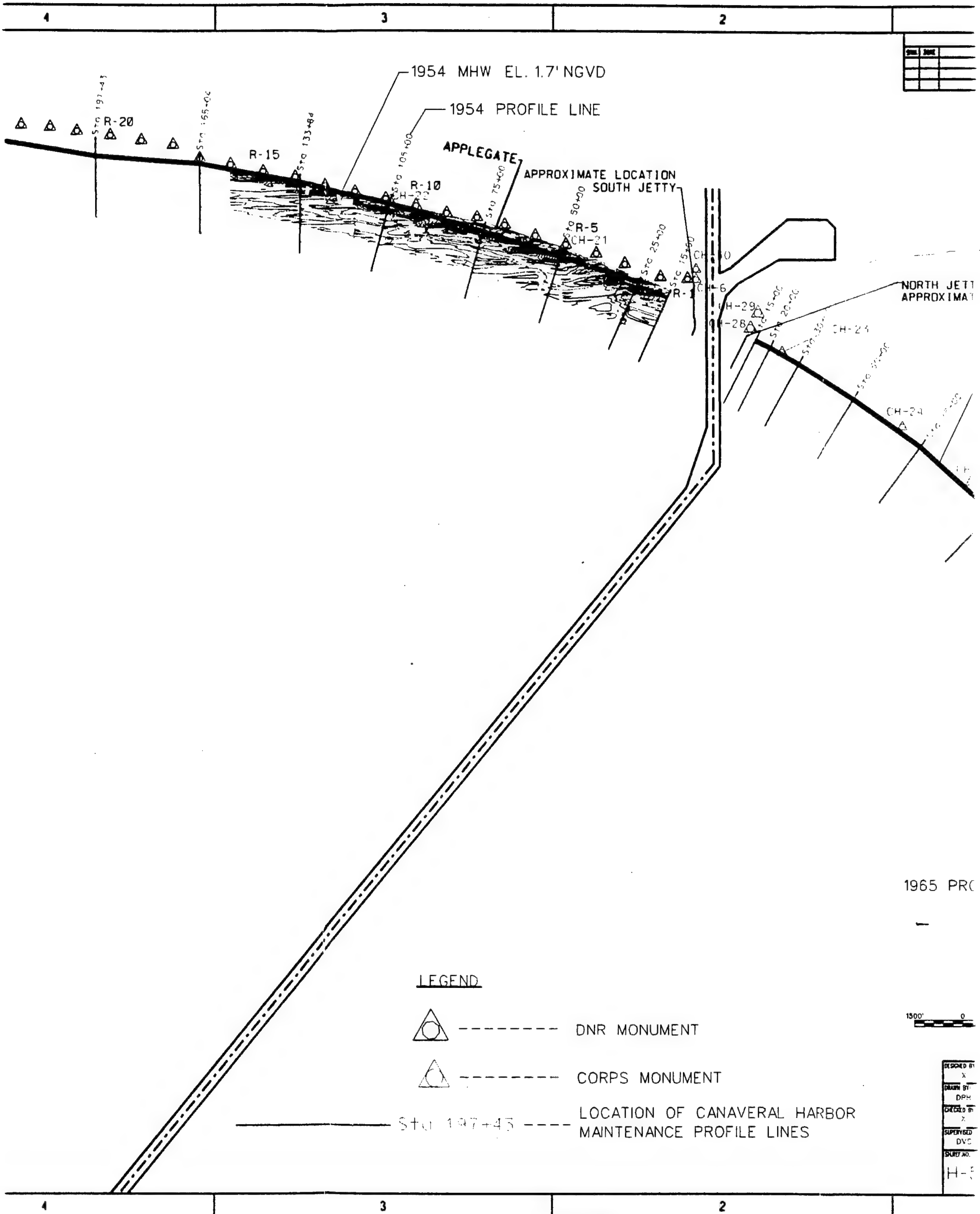
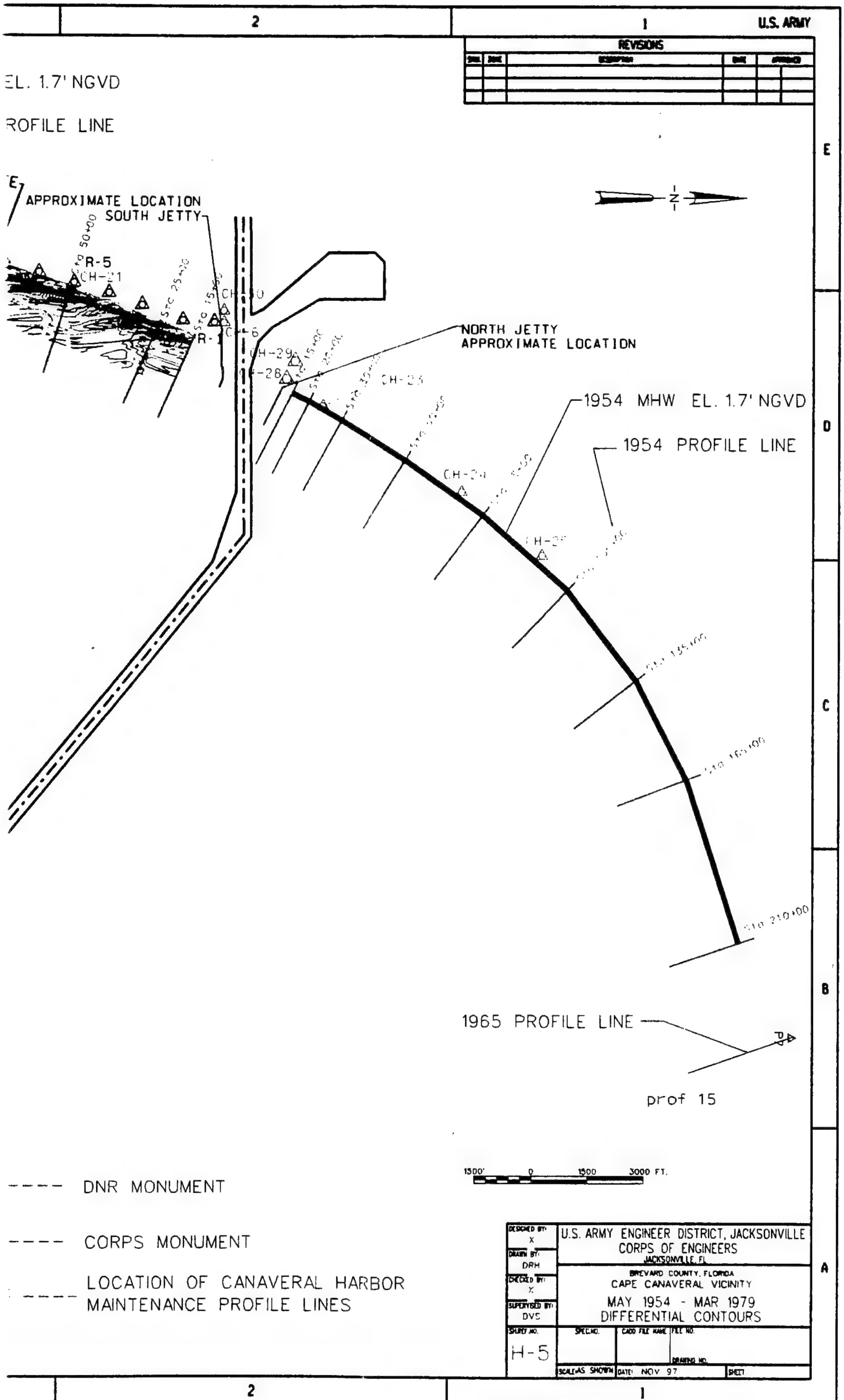


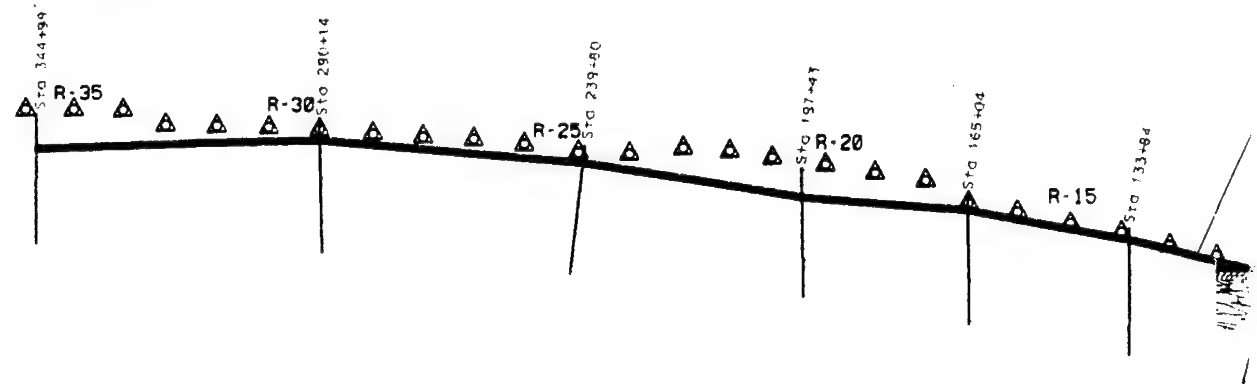
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
APPLEGATE
APPROXIMATE LOCATION SOUTH JETTY
R-20
R-15
R-10
R-5
CH-21
NORTH JETT
APPROXIMA
1965 PR
LEGEND
DNR MONUMENT
CORPS MONUMENT
Sta 197+43
LOCATION OF CANAVERAL HARBOR MAINTENANCE PROFILE LINES
DPH
DVS



U.S. ARMY
REVISIONS
EL. 1.7' NGVD
ROFILE LINE
APPROXIMATE LOCATION
SOUTH JETTY
R-5
CH-21
NORTH JETTY
APPROXIMATE LOCATION
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
1965 PROFILE LINE
prof 15
1500' 0 1500 3000 FT.
DNR MONUMENT
CORPS MONUMENT
LOCATION OF CANAVERAL HARBOR
MAINTENANCE PROFILE LINES
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS
JACKSONVILLE, FL
BREVARD COUNTY, FLORIDA
CAPE CANAVERAL VICINITY
MAY 1954 - MAR 1979
DIFFERENTIAL CONTOURS
DRAWN BY: DRH
SUPERVISED BY: DVS
H-5
SCALE: AS SHOWN
DATE: NOV 97

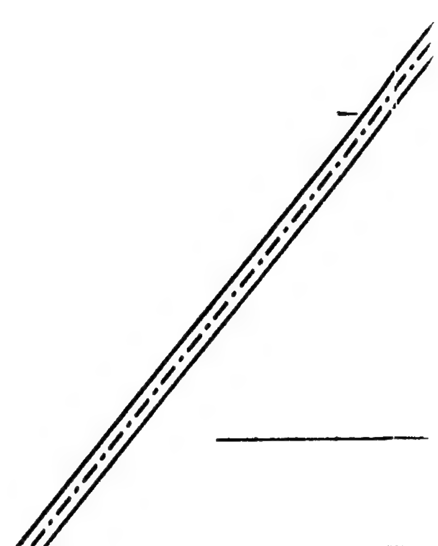
3 PLATE F-5

CORPS OF ENGINEERS | 4

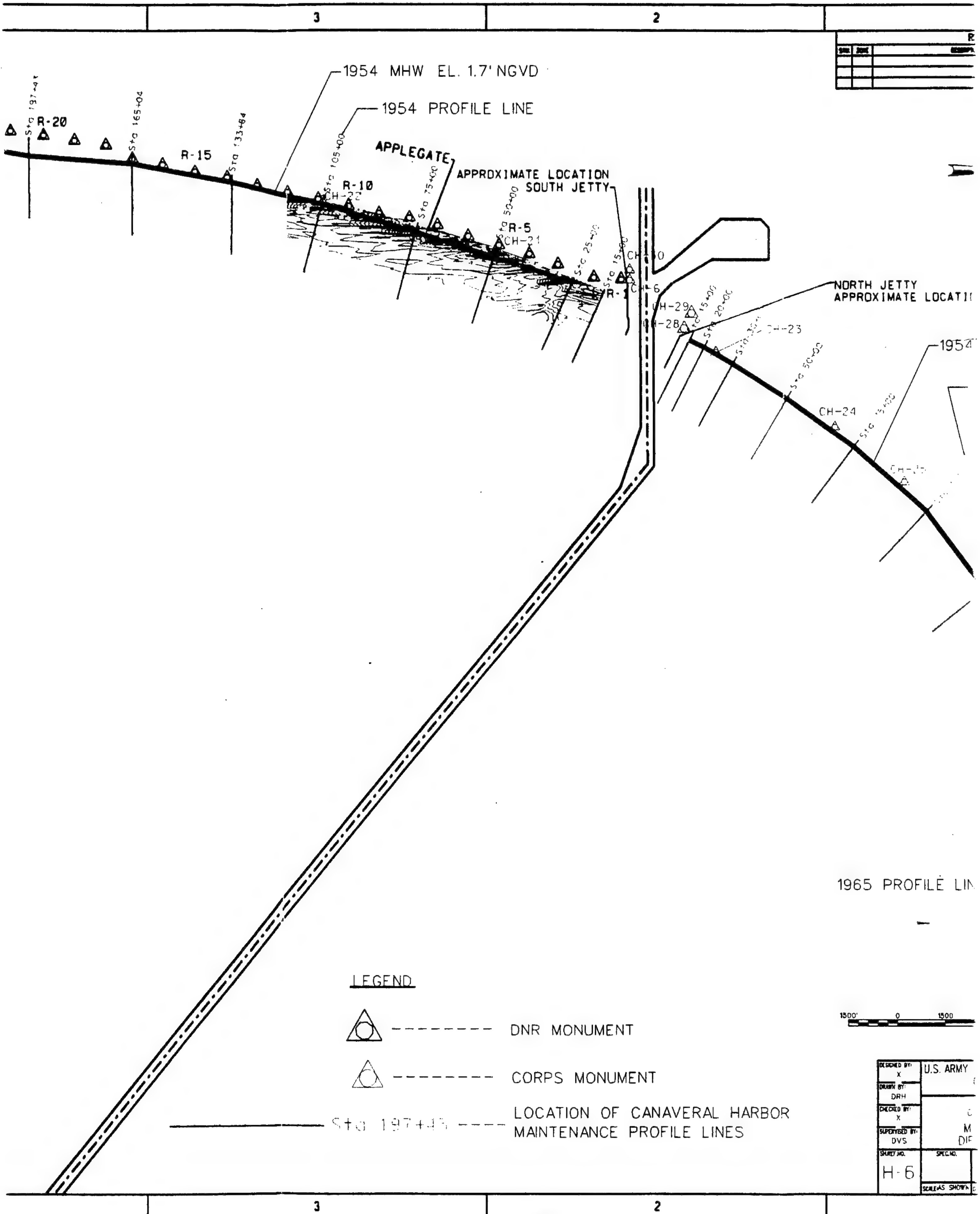


NOTES:
1. ONE FOOT CONTOUR INTERVAL.
2. VOLUMES WERE COMPUTED AS DIFFERENCES BETWEEN SURFACES GENERATED FROM EACH SURVEY.
3. VOLUME DIFFERENCES BETWEEN SURFACES WERE COMPUTED FROM LANDWARD LIMIT OF 58 SURVEY TO SEAWARD LIMIT OF THE -17 FOOT CONTOUR OF THE 1954 DATA.

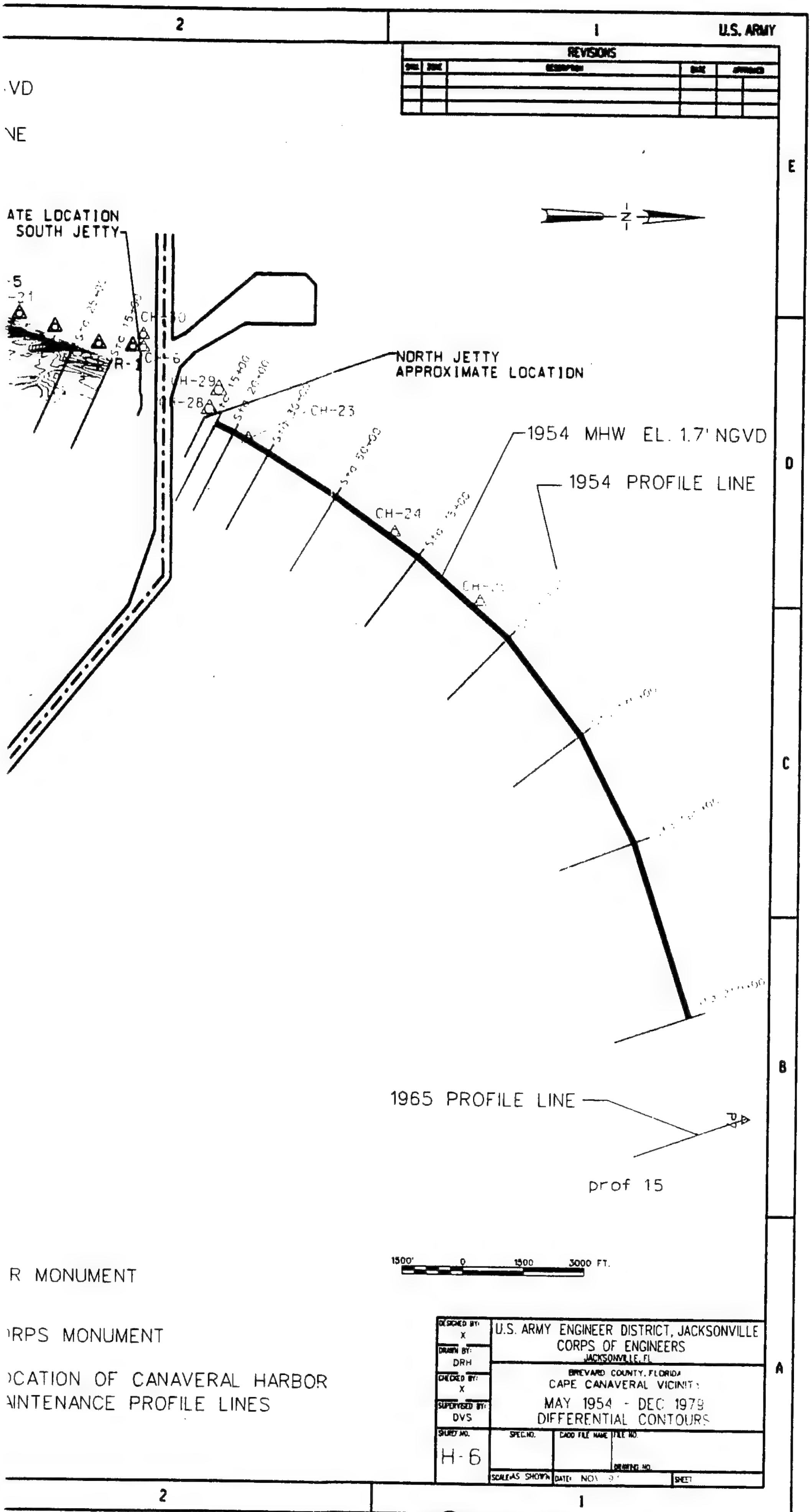
————	EROSION
————	ACCRETION
————	NO CHANGE



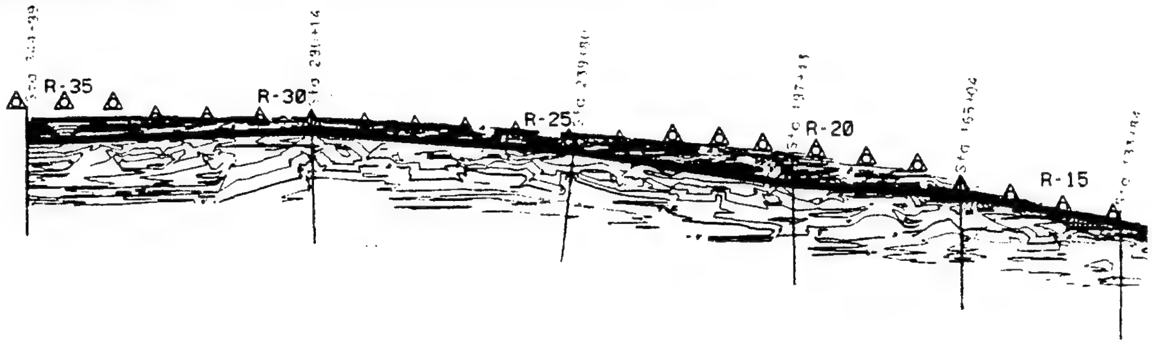
5 | 4



3
2
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
R-20
R-15
R-10
R-5
APPLEGATE
APPROXIMATE LOCATION
SOUTH JETTY
CH-22
CH-21
CH-6
CH-29
CH-28
CH-23
CH-24
NORTH JETTY
APPROXIMATE LOCATI
Sta 165+04
Sta 133+84
Sta 105+00
Sta 75+00
Sta 50+00
Sta 25+00
Sta 15+00
Sta 20+00
Sta 50+00
1965 PROFILE LIN
LEGEND
DNR MONUMENT
CORPS MONUMENT
Sta 197+45
LOCATION OF CANAVERAL HARBOR MAINTENANCE PROFILE LINES
1500'
0
1500
U.S. ARMY
DESIGNED BY: X
DRAWN BY: DRH
CHECKED BY: X
SUPERVISED BY: DVS
SHEET NO. H-6
SPEC NO.
SCALE AS SHOWN


U.S. ARMY
REVISIONS
VD
NE
ATE LOCATION
SOUTH JETTY
NORTH JETTY
APPROXIMATE LOCATION
CH-29
CH-23
CH-24
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
1965 PROFILE LINE
prof 15
1500' 0 1500 3000 FT.
R MONUMENT
RPS MONUMENT
CATION OF CANAVERAL HARBOR
AINTENANCE PROFILE LINES
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS
JACKSONVILLE, FL
BREVARD COUNTY, FLORIDA
CAPE CANAVERAL VICINITY
MAY 1954 - DEC 1979
DIFFERENTIAL CONTOURS
DRH
DVS
H-6
SCALE AS SHOWN

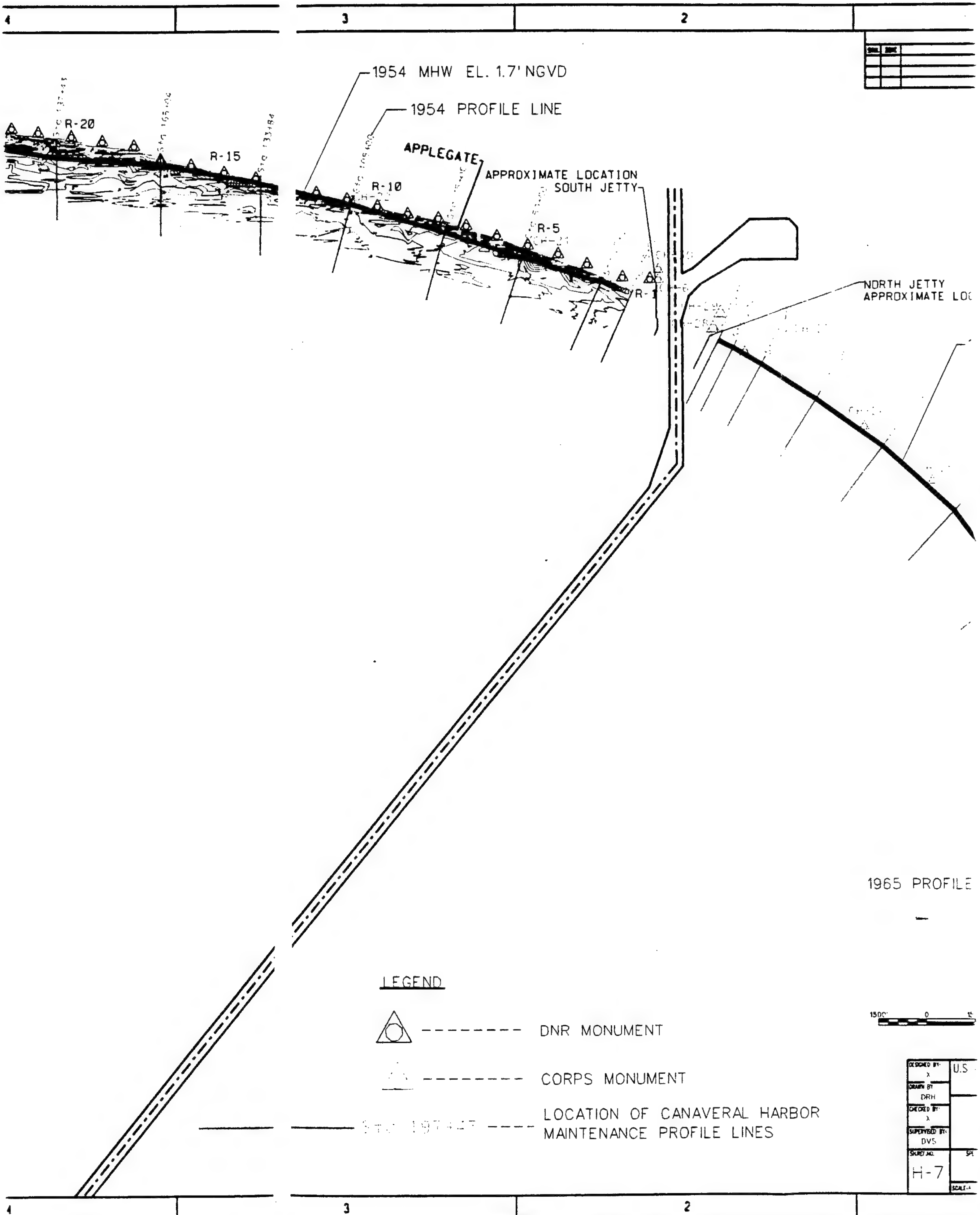
(3) PLATE F-6



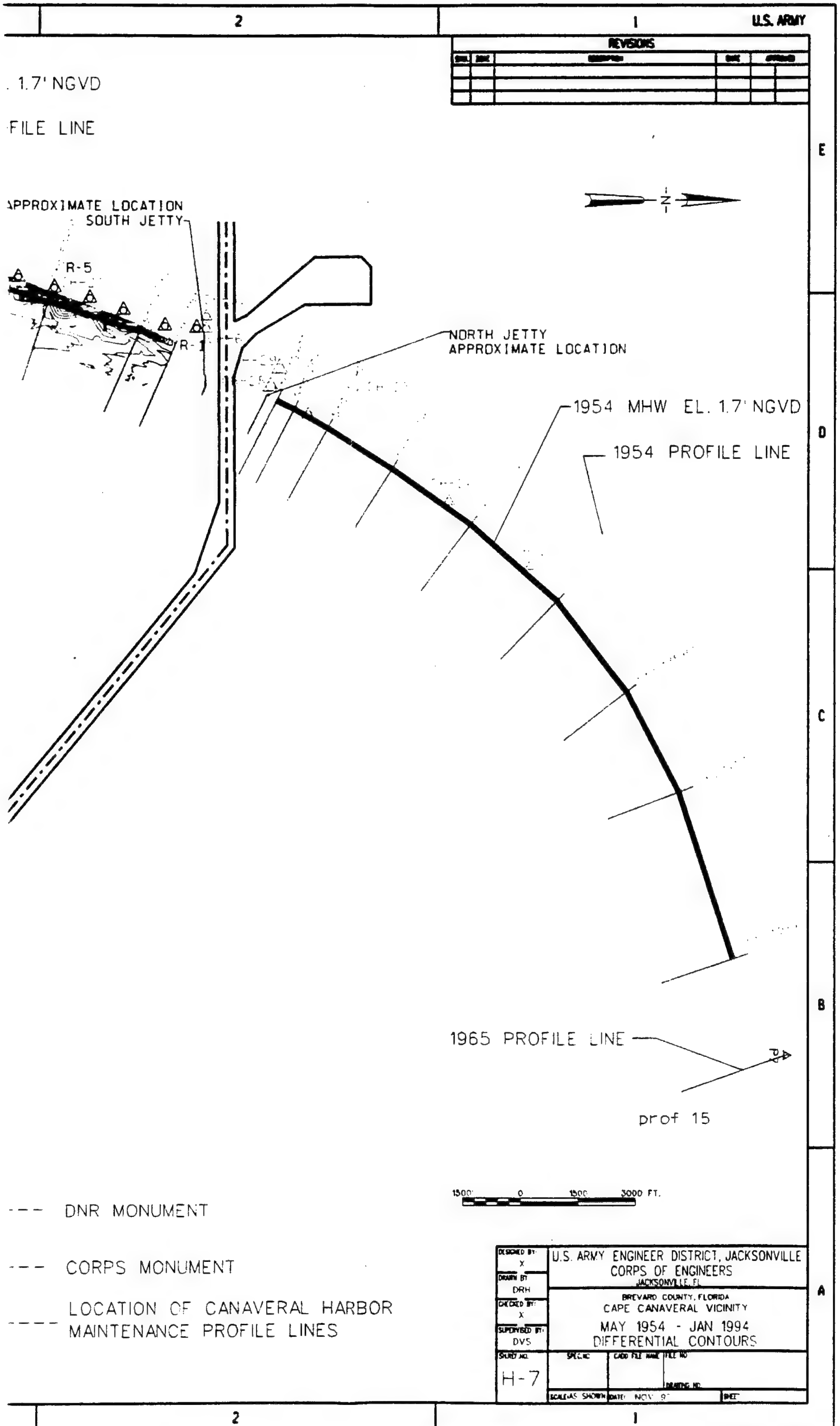
NOTES:

1. ONE FOOT CONTOUR INTERVAL.
2. VOLUMES WERE COMPUTED AS DIFFERENCES BETWEEN SURFACES GENERATED FROM EACH SURVEY.
3. VOLUME DIFFERENCES BETWEEN SURFACES WERE COMPUTED FROM LANDWARD LIMIT OF 58 SURVEY TO SEAWARD LIMIT OF THE -17 FOOT CONTOUR OF THE 1954 DATA.

————	EROSION
————	ACCRETION
————	NO CHANGE



1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
APPLEGATE
APPROXIMATE LOCATION
SOUTH JETTY
R-20
R-15
R-10
R-5
NORTH JETTY
APPROXIMATE LOC
1965 PROFILE
LEGEND
DNR MONUMENT
CORPS MONUMENT
LOCATION OF CANAVERAL HARBOR
MAINTENANCE PROFILE LINES
DRH
DVS
H-7
PL



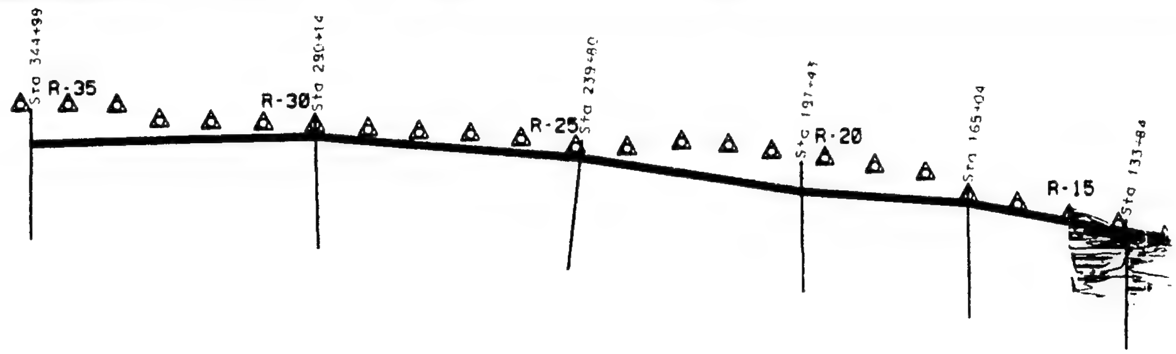
U.S. ARMY
REVISIONS
. 1.7' NGVD
FILE LINE
APPROXIMATE LOCATION
SOUTH JETTY
R-5
R-1
NORTH JETTY
APPROXIMATE LOCATION
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
1965 PROFILE LINE
prof 15
1500 0 1500 3000 FT.
DNR MONUMENT
CORPS MONUMENT
LOCATION OF CANAVERAL HARBOR
MAINTENANCE PROFILE LINES
DESIGNED BY: X
DRAWN BY: DRH
CHECKED BY: X
SUPERVISED BY: DVS
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS
JACKSONVILLE, FL
BREVARD COUNTY, FLORIDA
CAPE CANAVERAL VICINITY
MAY 1954 - JAN 1994
DIFFERENTIAL CONTOURS
H-7
SCALE: AS SHOWN

3

PLATE F-7

CORPS OF ENGINEERS

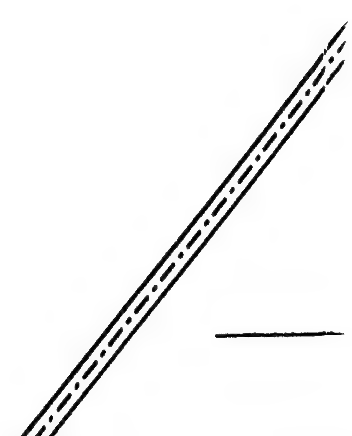
4



NOTES:

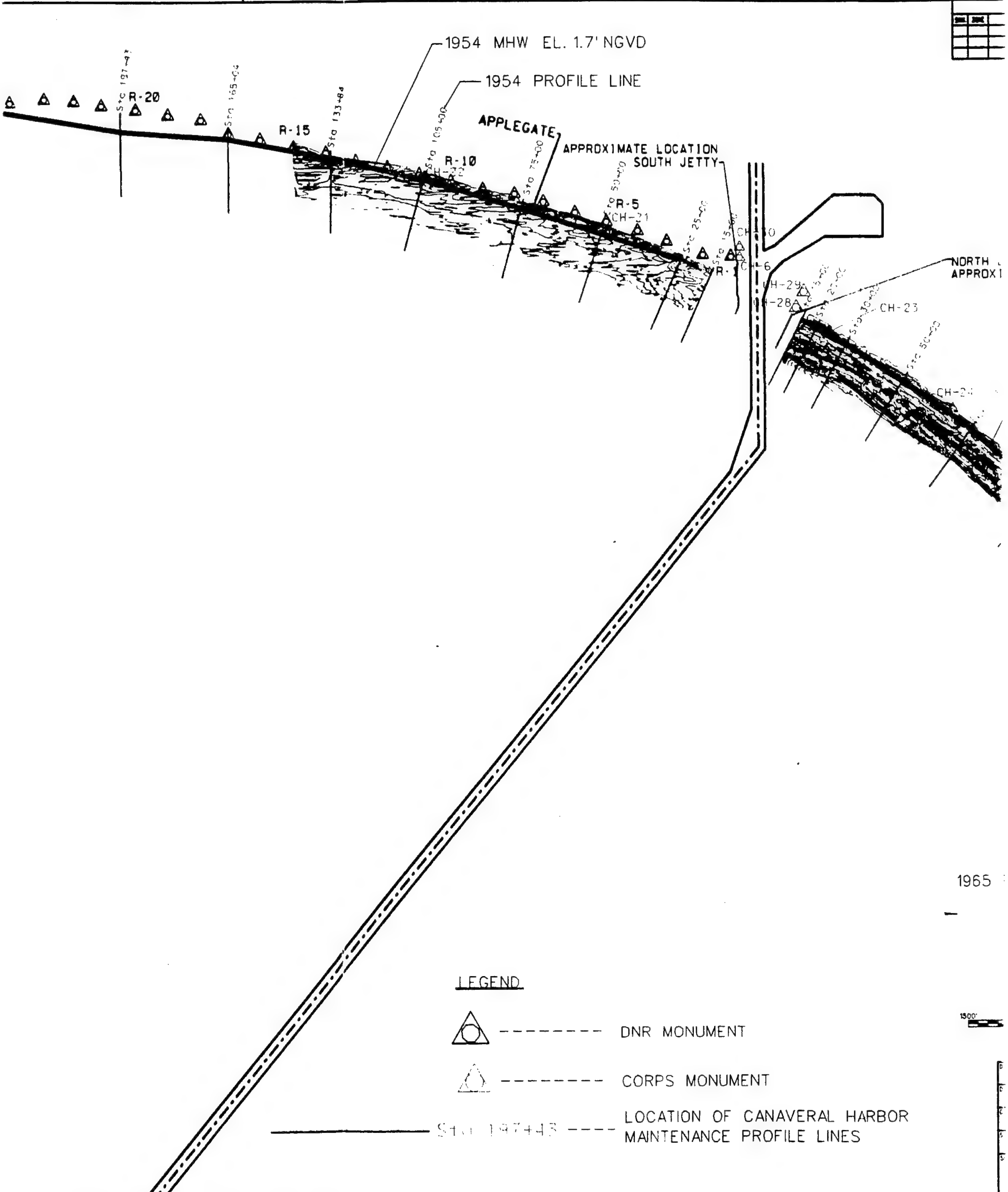
1. ONE FOOT CONTOUR INTERVAL.
2. VOLUMES WERE COMPUTED AS DIFFERENCES BETWEEN SURFACES GENERATED FROM EACH SURVEY.
3. VOLUME DIFFERENCES BETWEEN SURFACES WERE COMPUTED FROM LANDWARD LIMIT OF 58 SURVEY TO SEAWARD LIMIT OF THE -17 FOOT CONTOUR OF THE 1954 DATA.

————	EROSION
————	ACCRETION
————	NO CHANGE

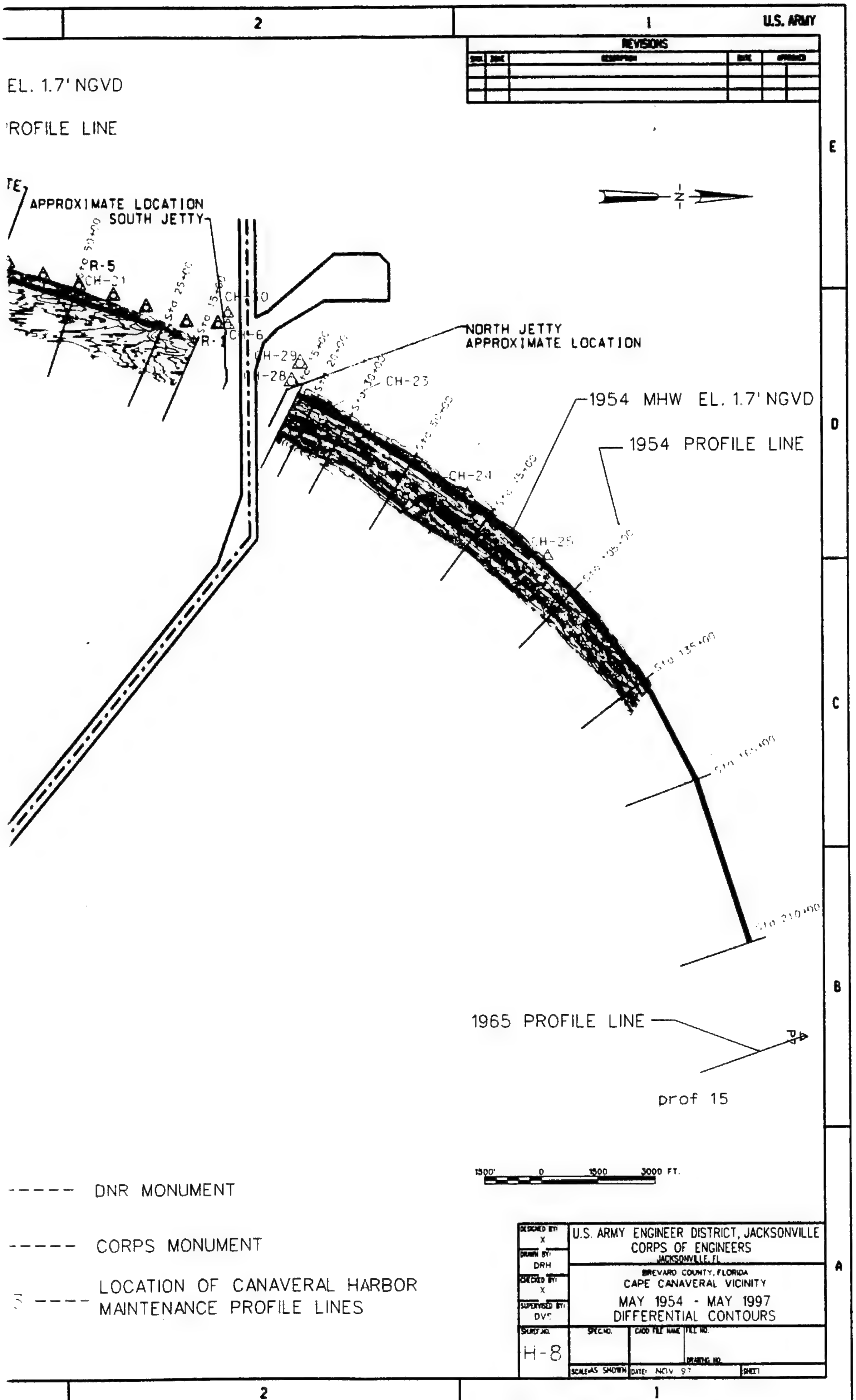


5 4

4	3	2


1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
APPLEGATE
APPROXIMATE LOCATION SOUTH JETTY
R-20
R-15
R-10
R-5
CH-21
CH-6
CH-23
NORTH
APPROXI
1965
LEGEND
DNR MONUMENT
CORPS MONUMENT
LOCATION OF CANAVERAL HARBOR MAINTENANCE PROFILE LINES

4	3	2

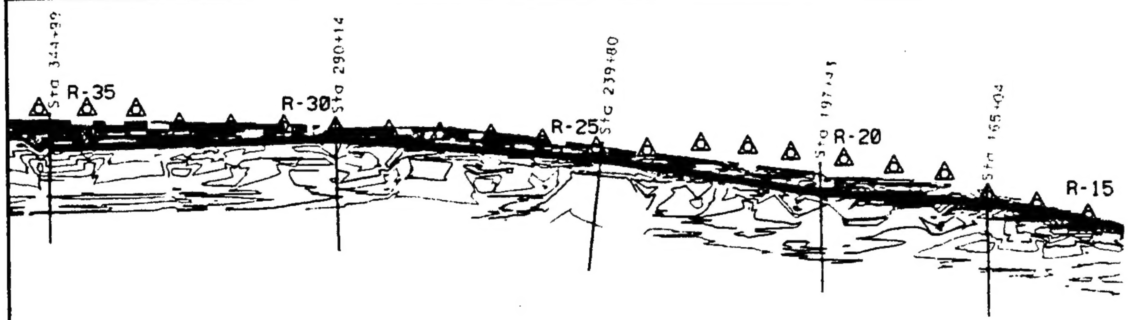

U.S. ARMY
REVISIONS
EL. 1.7' NGVD
ROFILE LINE
APPROXIMATE LOCATION
SOUTH JETTY
R-5
NORTH JETTY
APPROXIMATE LOCATION
CH-23
CH-24
CH-25
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
1965 PROFILE LINE
prof 15
1500' 0 1500 3000 FT.
DNR MONUMENT
CORPS MONUMENT
LOCATION OF CANAVERAL HARBOR
MAINTENANCE PROFILE LINES
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS
JACKSONVILLE, FL
BREVARD COUNTY, FLORIDA
CAPE CANAVERAL VICINITY
MAY 1954 - MAY 1997
DIFFERENTIAL CONTOURS
DRH
DVS
H-8
SCALE AS SHOWN
DATE: NOV 97

3

PLATE F-8

CORPS OF ENGINEERS

4



NOTES:
1. ONE FOOT CONTOUR INTERVAL.
2. VOLUMES WERE COMPUTED AS DIFFERENCES BETWEEN SURFACES GENERATED FROM EACH SURVEY.
3. VOLUME DIFFERENCES BETWEEN SURFACES WERE COMPUTED FROM LANDWARD LIMIT OF 58 SURVEY TO SEAWARD LIMIT OF THE -17 FOOT CONTOUR OF THE 1954 DATA.

EROSION
ACCRETION
NO CHANGE

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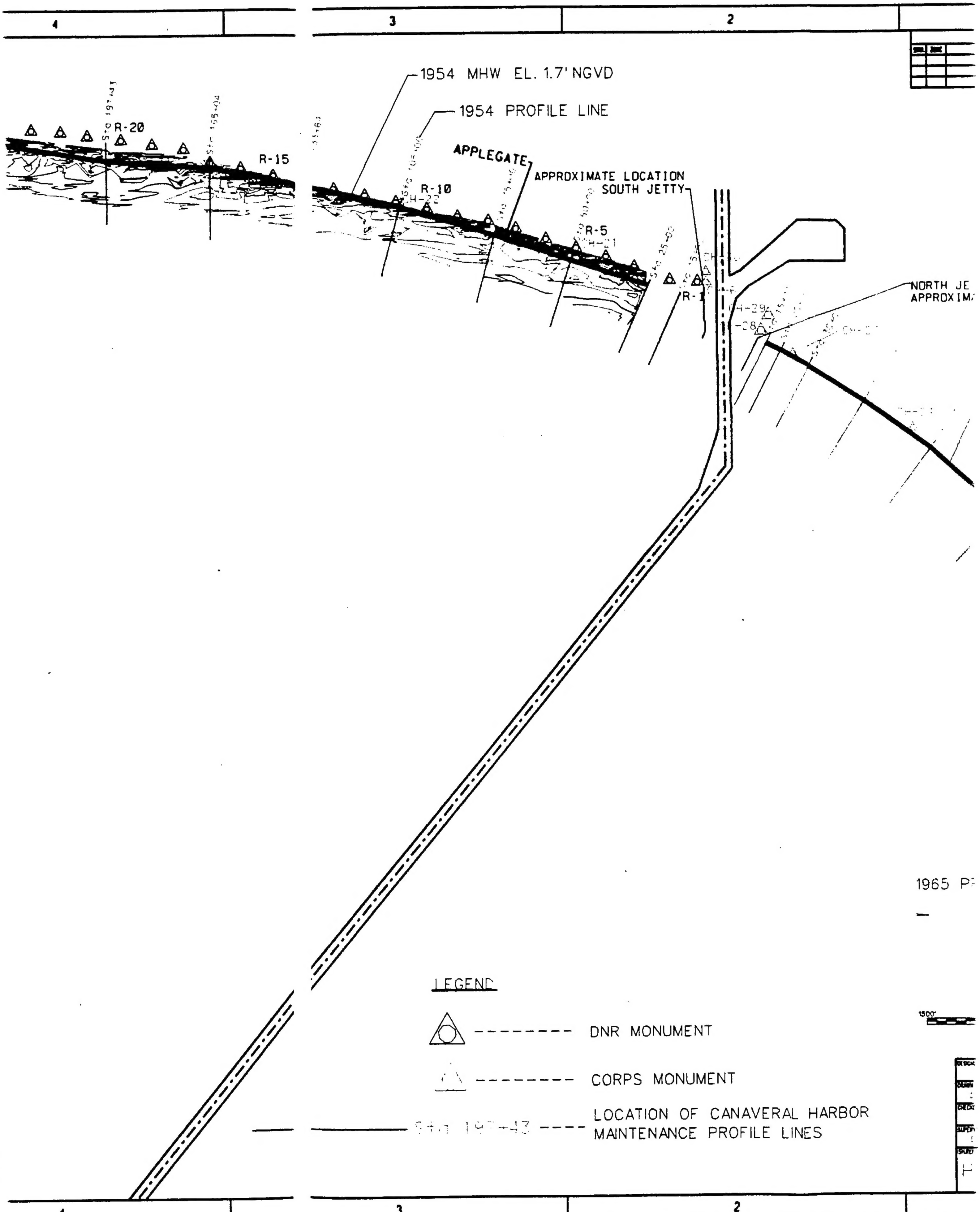
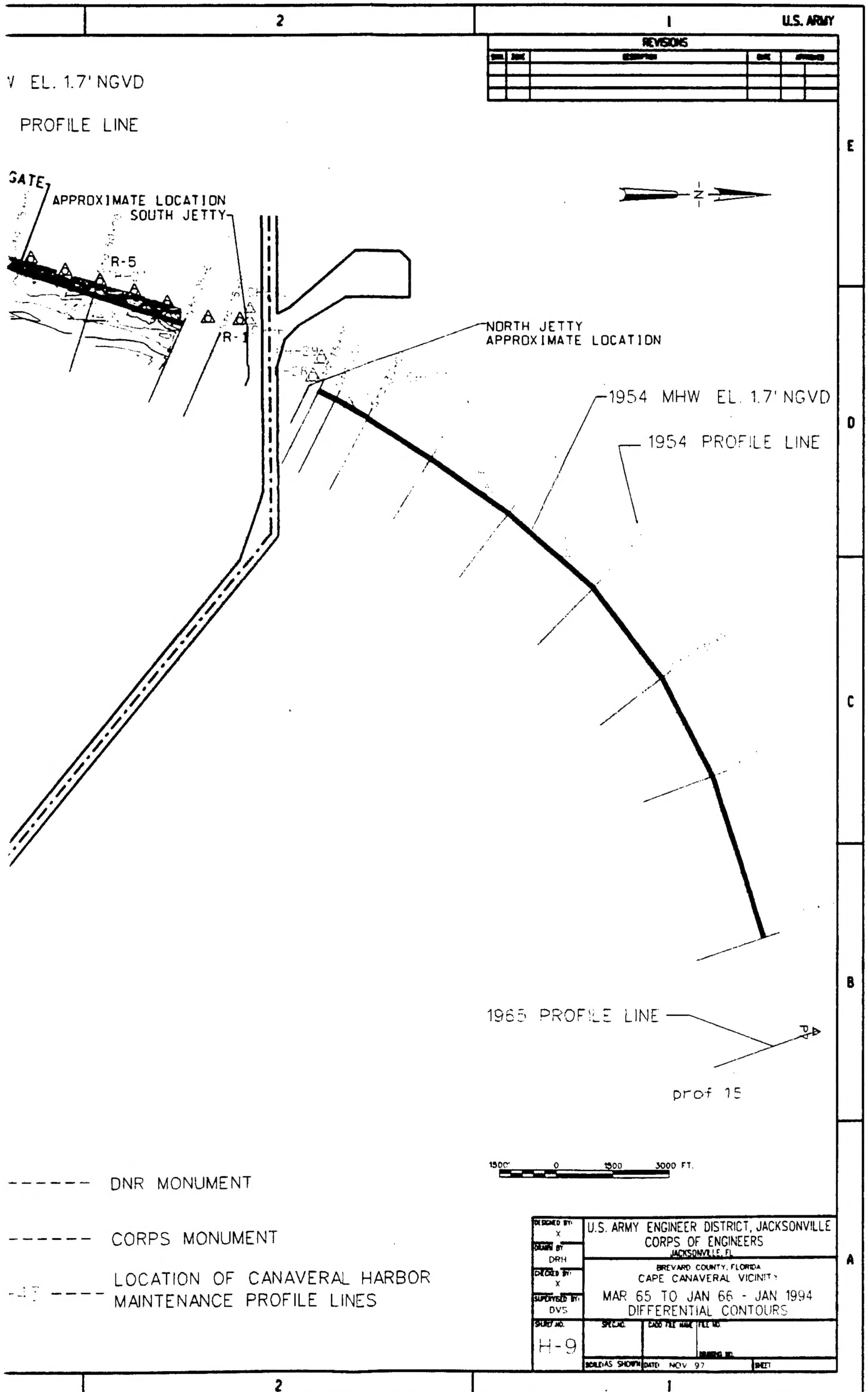

4
3
2
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
R-20
R-15
APPLEGATE
APPROXIMATE LOCATION
SOUTH JETTY
R-10
R-5
NORTH JE
APPROXIM
1965 P
LEGEND
DNR MONUMENT
CORPS MONUMENT
LOCATION OF CANAVERAL HARBOR
MAINTENANCE PROFILE LINES
1500'


2
1
U.S. ARMY
REVISIONS
V EL. 1.7' NGVD
PROFILE LINE
GATE
APPROXIMATE LOCATION
SOUTH JETTY
R-5
R-1
NORTH JETTY
APPROXIMATE LOCATION
1954 MHW EL. 1.7' NGVD
1954 PROFILE LINE
1965 PROFILE LINE
prof 15
E
D
C
B
A
1500' 0 1500 3000 FT.
DNR MONUMENT
CORPS MONUMENT
LOCATION OF CANAVERAL HARBOR
MAINTENANCE PROFILE LINES
DESIGNED BY: X
DRAWN BY: DRH
CHECKED BY: X
SUPERVISED BY: DVS
SHEET NO. H-9
U.S. ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS
JACKSONVILLE, FL
BREVARD COUNTY, FLORIDA
CAPE CANAVERAL VICINITY
MAR 65 TO JAN 66 - JAN 1994
DIFFERENTIAL CONTOURS
SCALE: AS SHOWN
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This report was prepared as an independent assessment of the coastal physical processes occurring along Brevard County, Florida. The study was conducted for the U.S. Department of Justice, Environment and Natural Resources Division, in its involvement with the lawsuit Applegate et al. versus the United States of America. Long-term regional beach change is evaluated by analysis of survey data on shoreline position, bathymetry, and beach profiles taken through time. In addition, analysis is specifically made for the properties of two test plaintiffs selected by the Court. Estimates of beach and dune erosion, if any, are calculated for the two test plaintiffs from date of purchase of the properties. Erosion of the beaches and dunes, principally attributed to storms, was estimated at the properties of the two test plaintiffs by compiling storm data and calculating beach and dune change with a numerical model.

14. SUBJECT TERMS

Bathymetric change	Florida
Brevard County	Shoreline change
Canaveral Harbor	Storm-induced beach change
Cape Canaveral	U.S. Army Corps of Engineers
Coastal processes	U.S. Department of Justice
Down-drift impacts of coastal structures	

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